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ISBI Practice Guidelines for Burn Care☆

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ABSTRACT

Practice guidelines (PGs) are recommendations for diagnosis and treatment of diseases and injuries, and are designed to define optimal evaluation and management. The first PGs for burn care addressed the issues encountered in developed countries, lacking consideration for circumstances in resource-limited settings (RLS). Thus, the mission of the 2014–2016 committee established by the International Society for Burn Injury (ISBI) was to create PGs for burn care to improve the care of burn patients in both RLS and resource-abundant settings. An important component of this effort is to communicate a consensus opinion on recommendations for burn care for different aspects of burn management. An additional goal is to reduce costs by outlining effective and efficient recommendations for management of medical problems specific to burn care. These recommendations are supported by the best research evidence, as well as by expert opinion. Although our vision was the creation of clinical guidelines that could be applicable in RLS, the ISBI PGs for Burn Care have been written to address the needs of burn specialists everywhere in the world.

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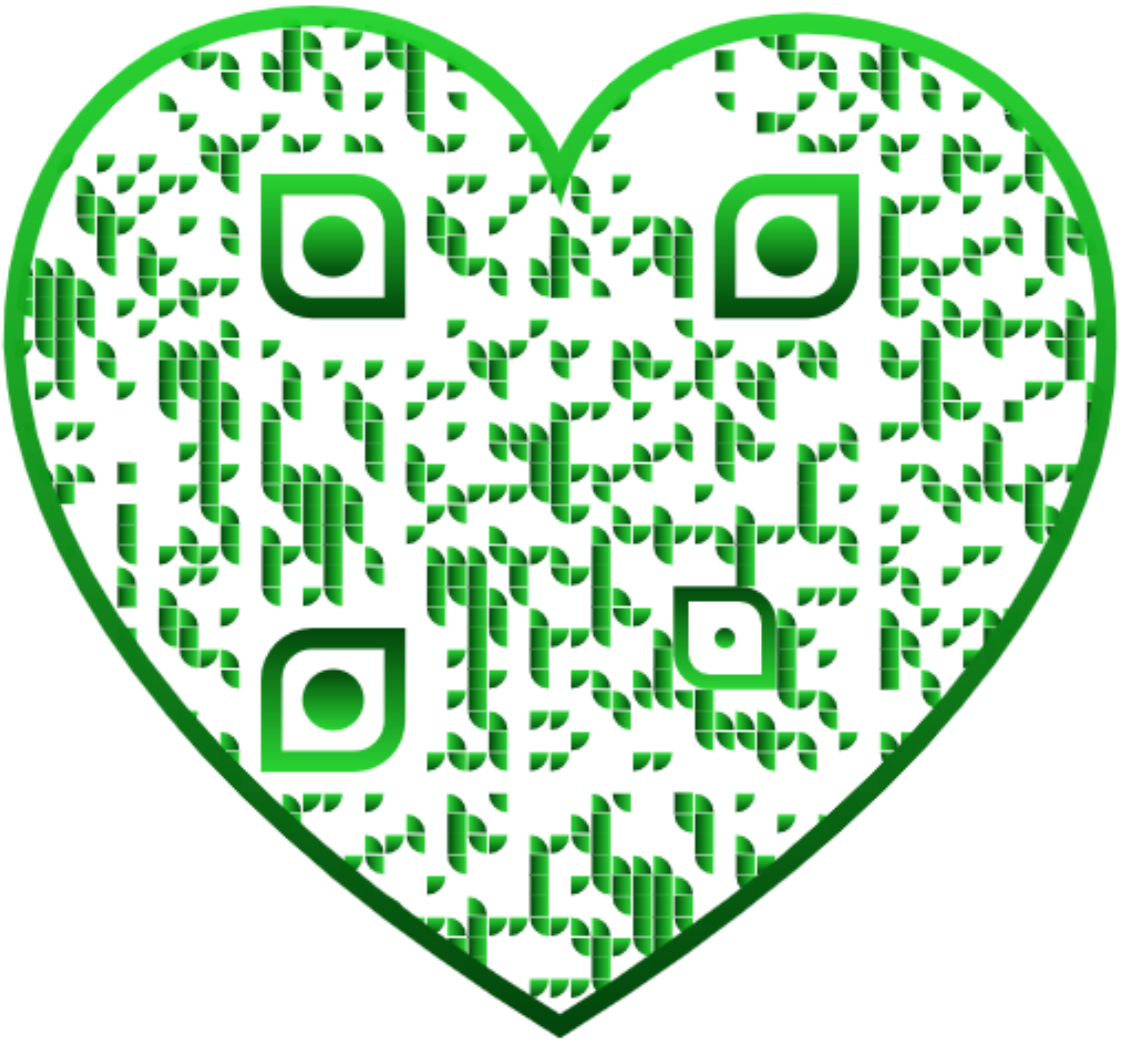

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ISBI Practice Guidelines for Burns Care

1. Introduction

1.1. Background

Practice guidelines (PGs) are recommendations for diagnosis and treatment of diseases and injuries. These recommendations, which are supported by systematic reviews of the literature as well as assessments of the benefits and harms of the presented options, are developed through an assiduous interactive process among a dedicated panel of experts [1]. The purpose of setting forth practice guidelines is to define the most effective and efficient methods of evaluation and management [2–5].

The multiple objectives for PGs include standardization of care, quality improvement, reduction of risk, and optimization of cost-benefit ratios. PG recommendations focus on important clinical options, often-critical decision points and subsequent courses of action which are most likely to influence outcomes. The degree to which these recommendations are crafted upon evidence-based medicine is dependent on the existence of high-class scientific studies, the concurrence of conclusions among published studies, and the consensus of experienced practitioners. In the end, the utility of PG recommendations may rest less on scientific certainty and more on decisions based on costs, benefits, potential harms, values and preferences. It has been said, ''. . .While knowledge is more than research evidence, knowledge translation strategies can harness the power of scientific evidence and leadership to inform and transform policy and practice'' [6].

Several attributes of PGs ensure guideline credibility and utility. These attributes include validity, reliability and reproducibility, clinical applicability, clinical flexibility, clarity, multidisciplinary process, scheduled review, and documentation [7]. Construction of high-quality PGs requires a standardized yet punctilious process; such a process has been elaborately described by the Guidelines Review Committee of the World Health Organization (WHO) in the *WHO Handbook for Guideline Development* [8].

Creation of PGs for burn care began in 1998–1999 and culminated in the publication of a supplement to the *Journal of Burn Care and Rehabilitation* in 2001 [9]. This effort was supported by the Evidence-based Guidelines Group, the American Burn Association (ABA), and Paradigm Health Corporation. Since the publication of those PGs in 2001, the ABA, acting through its Committee for the Organization and Delivery of Burn Care, has published PGs on burn shock resuscitation [10], electrical injuries [11], pain [12], prophylaxis of deep venous thrombosis [13], and ventilator-associated pneumonia [14]. A summary of clinical guidelines in the management of burn was published in 2014 [15].

> The mission of the ISBI Practice Guidelines Committee is to create a set of clinical guidelines to improve the care of burn patients and reduce costs by outlining recommendations for management of specific medical problems encountered in burn care, recommendations which are supported by objective and comprehensive reviews of the literature as well as by expert opinion. Our vision is that these guidelines for burn care in resource-limited settings (RLS) will recognize the current best and most cost-effective methods of treatment.

The International Society for Burn Injuries (ISBI) has long recognized a need to provide burn care practitioners with recommendations for patient care. The motto of ISBI, ''One World, One Standard of Care,'' espoused by Past President David Mackie of the Netherlands in 2012, speaks directly to the need to harmonize practice across the world of clinical efforts. This effort is likely to best achieve optimal clinical outcomes after burn. In 2012, the International Network for Training, Education and Research in Burns (Interburns®) developed a set of operational standards for burn care services in Resource-Limited Settings[3] (RLS). These standards define the human and physical resources needed to provide good clinical outcomes [9]. The Interburns® report summarized the knowledge, skills, facilities and equipment required to achieve this end; the complement to that report is the precise elaboration of the clinical options which are the focus of education and training efforts.

With this in mind, the current ISBI president, Rajeev Ahuja of Delhi, undertook the challenge of guiding a panel of burn experts through the process of writing much-needed PGs that would be applicable in all settings regardless of resource availability. On March 24, 2014, the first face-to-face (F2F) meeting was held in Boston, Massachusetts, at which time a preliminary discussion involved the mission and vision statements, composition and function of the subcommittees, elaboration of the list of topics to be addressed, description of

[3] Throughout these documents, the term resource-limited settings (RLS) will be used to define medical situations in which there are inadequate personnel, training, supplies and equipment. Although most RLS occur in low- and middle-income countries (LMIC), there are also zones of poverty in upper middle- and high-income countries as well. Additionally, mass casualty situations can turn any setting into one in which resources are limited.

the terms of reference, visualization of the end product, and creation of a broad time frame for completion. Between this first meeting and the next F2F meeting held in October 2014, all communication was conducted by electronic mail (email) and through virtual meetings.

These PGs, intended for a primary audience of health professionals responsible for providing acute care and rehabilitation for burn patients, focus on acute care and rehabilitation. Although the PGs have been crafted to include recommendations germane to RLS, the material should be pertinent in high-resource settings as well. These PGs can also be used by policy-makers, public health experts, and hospital managers. The information in these PGs can be included in tools for pre- and in-service training of health professionals, and to improve their knowledge, skills, and performance in burn care.

Table 1 – Topics developed in current ISBI practice guidelines.

- Organization and delivery of burn care
- Initial assessment and stabilization
- Smoke inhalation injury: diagnosis and treatment
- Burn shock resuscitation
- Escharotomy and fasciotomy in burn care
- Wound care
- Surgical management of the burn wound
- Nonsurgical management of burn scars
- Infection prevention and control
- Antibiotic stewardship
- Nutrition
- Rehabilitation: positioning of the burn patient
- Rehabilitation: splinting of the burn patient
- Pruritus management
- Ethical issues
- Quality improvement

1.2. *Methods*

The ISBI Practice Guidelines Committee was divided into two subcommittees: the Steering and Advisory Subcommittees. The role of the Steering Subcommittee was to perform editorial functions, conduct reviews of the literature, research additional sources of expert opinion, ensure uniformity of quality throughout the document, and confirm adherence to structure format. Members of the Advisory Subcommittee were selected because of their experience providing burn care in RLS, or because they hold positions as Regional Representatives on the ISBI Executive Committee. The Advisory Subcommittee focused its content review on the proposed protocols for value (effectiveness/cost), feasibility, and preferences. Although face-to-face meetings were held in Boston and Sydney in 2014, insufficient funding precluded the attendance of all participants. The bulk of the work therefore was accomplished by email communications using a modified Delphi method. All 32 committee members completed conflict-of-interest forms; none of these declared a potential conflict of interest in the subject matter.

The Steering Subcommittee initiated its work by enumerating the topics to be included because of their clinical relevance. A number of revisions were made to this first iteration of PGs. The finalized list of topics now appears as the subjects of the individual sections in the documents that follow (Table 1). The development of additional important topics has been deferred until the next round of PGs and will be identified in the work to be undertaken between 2017 and 2018.

Once the topics were selected, each member of the Steering Subcommittee was charged with developing one to two assigned topics. The stages of this development included review of the literature, crafting the recommendations, providing justification for the recommendations, and elucidating balance of benefits and harms, values and preferences, and costs. After the recommendations were written, they were circulated by email among the other members of the Steering Subcommittee. Further discussion led to revised recommendations, which were then sent electronically to the members of the Advisory Subcommittee. Feedback from the Advisory Subcommittee was returned to the Steering Subcommittee, and after further revisions, the recommendations and accompanying text were sent to the Advisory Subcommittee. Following the final review of all content for each topic by the Advisory Subcommittee, the Steering Subcommittee completed its revisions. The chapters (topics) were then sent to the medical editor to prepare for submission to the journal editor.

The following process was used for evidence retrieval prior to synthesis of recommendations. Methodical literature reviews were performed using MEDLINE (accessed via PubMed on March 27, 2015, at http://www.ncbi.nlm.nih.gov/pubmed) and the Cochrane Library. Parameters used in the searches included the following for each topic:

- English language;
- Humans;
- Published in last 10 years;
- Article types included Clinical Trial, Comparative Study, Controlled Clinical Trial, Multicenter Study, Observational Study, Randomized Controlled Trial, Review, Systematic Reviews, and Meta-analysis.

The primary purpose of this investigation was to identify high quality, systematic reviews, meta-analyses, and previously published practice guidelines. The secondary purpose was to identify observational and interventional clinical studies relevant to each topic. Furthermore, relevant non-English articles and studies from RLS were sought. Because of the paucity of randomized, prospective, controlled trials, observational studies were accepted as sources of evidence, recognizing the inherent bias of such design.

One of the features distinguishing this effort from work on previously published PGs in burn care is the attempt to bridge the gap between knowledge and practice by acknowledging the real-life constraints in RLS that challenge implementation of best practices. A summary of the balance of benefits and harms is presented, followed by allusion to values, preferences, and costs. *Value* is defined as the relative importance or worth of the consequences of a decision, including ethical considerations. *Preferences* lead to different decisions in different settings due to different values. *Costs* were estimated to help users evaluate the potential consequences of different

Table 2 – Subcommittee membership.

The steering and advisory sub-committees included the following individuals.

Steering Subcommittee
Rajeev B. Ahuja (India)
Nicole Gibran (US)
David Greenhalgh (US)
James Jeng (US)
David Mackie (Netherlands)
Amr Moghazy (Egypt)
Naiem Moiemen (UK)
Tina Palmieri (US)
Michael Peck (US)
Michael Serghiou (US)
Stuart Watson (UK)
Yvonne Wilson (UK)

Advisory Subcommittee:
Ariel Miranda Altamirano (Mexico)
Bechara Atieh (Lebanon)
Alberto Bolgiani (Argentina)
Gretchen Carrougher (US)
Dale Edgar (Australia)
Linda Guerrero (Columbia)
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Vinita Puri (India)
Nyoman Putu Riasa (Indonesia)
Fiona Wood (Australia)
Jun Wu (China)
Xia Zhao-Fan (China)
Paul van Zuijlen (Netherlands)

practices, although these PGs were not constructed with the use of detailed economic evaluations (such as cost-benefit ratios). In addition to direct financial cost, these estimated costs included the following:

- Opportunity cost
  - Loss of potential gain from other alternatives not utilized
- Analysis of resource use
  - Identification of type of resource associated with the intervention
  - Measurement of how much of the resource is used
  - Monetary evaluation of resource expenditure
- Resource implications—feasibility
  - Training and supervision requirements
  - Referral support
  - Equipment and infrastructure requirements
  - Monitoring and evaluation

The objective of the ISBI guidelines is to offer concise (at-a-glance), evidence-based recommendations to support universal applicability, for use both under austere conditions and in situations where providers have access to advanced health care resources. For many of recommendations, however, a paucity of evidence necessitates some imprecision in our statements. To add granularity to these recommendations, therefore, some recommendations are followed by a set of frequently asked questions (FAQs).

1.3. *Dissemination plan*

The ISBI Practice Guidelines are perceived as a living document with planned reconsideration on emergence of fresh, strong evidence, and therefore, there is a commitment to undertake periodic review. The information will first be distributed through the journal *Burns*, followed by provision of open access via the Internet.

Acknowledgements

The International Society for Burn Injuries gratefully acknowledges the contributions of many individuals to the development of these guidelines. Membership of the Steering and Advisory Subcommittees are listed in Table 2. Additional contributions were made by Drs. Damien Carter, Pallab Chatterjee, and Lyndsay Olsen Deeter to sections on *Organization and Delivery of Burn Care*, *Nonsurgical Management of Burn Scars*, and *Initial Assessment and Stabilization*, respectively. Administrative support was provided by Ms. Elisabeth Greenfield, Administrator of ISBI. Finally, the superb editing skills of Ms. Andrea Sattinger made it possible to adapt several different writing styles from across the globe into a consistent, comprehensible document.

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2. Organization and delivery of burn care

Recommendation 1

All regions should have an organized system of care for injured persons. This includes an organized system of burn care delivery.

2.1. *Considerations in formulating Recommendation 1*

Minimal evidence in the literature supports the establishment of dedicated burn units/centers to provide comprehensive burn care. In the United States, Europe and Australia, much of the literature used to support the establishment of burn care systems and establishment of treatment standards, such as center verification, is largely based on the extensive work accomplished regarding trauma care systems [16]. Very strong data are available to support trauma care systems where the injuries may result in death within minutes to hours [17]. Given that burns are cared for in different albeit similar clinical centers, they have not been included in the body of data that has formed the basis of modern trauma care systems. In fact, the development of transfer criteria to burn centers, as well as the American Burn Association (ABA)/American College of Surgeons (ACS) verification program, were spin-offs from the ACS Committee on Trauma-derived trauma center verification process [18].

Several studies based on large administrative databases have consistently shown no improvement in mortality or morbidity among general hospitals, non-verified centers, or verified centers [18,19]. However, this paucity of evidence to support burn center development should not be taken as an argument to de-emphasize development of these critical resources.

Several single-center studies have demonstrated improved outcomes with certain populations [20,21]. Notable single-center studies have demonstrated improved outcomes (mortality and morbidity) for burns >50% total body surface area (TBSA), children less than 12 years of age, and inhalation injuries treated at verified centers [18]. An organized system of burn care delivery is strongly recommended for treating pediatric burns and extensive or critical burns (i.e., >40% TBSA, inhalation injuries, etc.); but when faced with resource constraints, burns of lesser intensity or uncomplicated burns may well be managed in general surgical or trauma units.

Globally, burns continue to represent the most severe model of traumatic injury, with considerable challenges to functional and psychological recovery [22]. Over the past 50 years, care providers in high-income countries (HIC) have seen dramatic improvements in survival after burn. Whereas in 1952, a 25-year-old man with a 45% TBSA burn would have an expected 50% survival rate [23], today, burn size in excess of 80% would have the same expected chance for survival. Advancements in effective burn care over the past half-century result from both phenomenal advances in burn and critical care science and from organization and delivery of multidisciplinary burn care. Without basic science, the translational and clinical research innovations in the areas of resuscitation, inhalation injury, early excision and grafting, infection control, and metabolic modulation, would have made these greatly improved statistics impossible. However, without the collaboration of multidisciplinary burn teams, these scientific and clinical successes could never have been achieved. Many of these advances were the result of nurtured scientific research in dedicated burn units [24]. These advancements have benefited burn care in burn centers and general hospitals alike.

Historically, burn-injured patients were aggregated in a corner of a surgical ward. With the unsightly wounds, odors, and pain management challenges, many providers were reluctant to care for this complicated patient population. Fortunately, this spurred the development of a cadre of dedicated health care personnel committed to improving outcomes for this unique patient population [25]. The organization of burn centers created a self-sustaining multidisciplinary structure of clinical experience leading to research inquiry that has led to many of the advancements in burn care that we know today. Through the day-to-day sharing of observations and experiences and the efforts to answer the questions that arise at the bedside, those individuals affiliated with dedicated burn centers are responsible for the dramatic advancement of the field.

2.1.1. *Balance of benefits and harms*

Effective, modern, integrated burn care for a metropolis or a nation must be seen as a ‘‘team sport.’’ Modern burn care is such a complex entity; good and systematic positive outcomes will result only from high-level organization and premeditated coordination of disparate resources spanning multiple people and organizations. The only imaginable harm from systematic organization is the need to surrender some degree of total individual autonomy, and this can sometimes be a challenge in organizational behavior.

2.1.2. *Values and preferences*

Treatment of severe burns consumes enormous resources including that of workforce efforts, dressing supplies and

pharmaceuticals. Dedicated regional burn units allow cohorting of these resources to maximize efficiency and expertise. Unfortunately, no data are available to assist in determining the ideal burn center size (in terms of number of beds). The question must at some point be resolved as to whether an upper limit can be identified for the number of patients in a burn unit who can be safely cared for while providers maintain an environment that promotes optimal outcomes. For resource-limited settings (RLS), these challenges strongly support the argument for regionalization and concentration of burn care resources in fewer locations [26].

2.1.3. *Costs*

Even in the most resource-deprived settings, the intellectual industry and prescience to team-build and organize is essentially a ''free'' exercise. Examples of good teamwork exist throughout the world; teamwork is one of the defining attributes of the human condition.

Recommendation 2

An organized system of acute, chronic and rehabilitative care should be provided for patients with burns.

2.2. *Considerations in formulating Recommendation 2*

Significant evidence in the literature supports the establishment of burn units to provide acute and follow-up care. Though there are no randomized controlled trials investigating the issue, the collective experience of comprehensive burn therapy provided by burn units around the world provides ample data to support longitudinal care of this trauma population. It is well established in the literature that the late sequelae of burns cause considerable morbidity, reduce return-to-work rates, and cause considerable psychological effects [27]. Whereas mortality rates have dwindled for all but the most severe burns and inhalation injuries, restoring form and function have become the hallmarks of excellent burn care [28]. Existent data support the notion that multidisciplinary management is key to the long-term functionality of burn survivors.

An effective burn center involves more than bricks and mortar, and operation as a unit within a hospital. The primary strength of an exceptional burn center relates to the individuals who care for the patients: developing standardized operating procedures, dedicating themselves to educating others about burn care, performing research, participating in prevention efforts, and advocating for their patients [29]. A lone burn specialist cannot effectively deliver quality and excellence in burn care. The nature and complexity of the acute surgical and medical management of burns, coupled with the effects of injuries on patient body-image, self-perception and social circumstances, requires a multidisciplinary skill set to provide optimal care. Additionally, the prolonged hospitalization and need for extended nursing and therapy support differentiates the type of care that a burn team must deliver compared with the care provided by elective surgical practices or even trauma services.

The multidisciplinary team that best serves the needs of the burn patient includes burn surgeons, burn-trained nurses, physical and occupational therapists, pharmacists, and dietitians [18]. Depending on the acuity of management required and the complexity of arrangements with community resources, patients with burns also benefit from dedicated anesthesiologists, respiratory therapists and social workers. Over the past 25 years, improved survival rates have allowed burn providers to focus on burn survivors' long-term functional and psychological outcomes and quality of life. As a result, more burn units have integrated relationships with physiatrists and rehabilitation facilities as well as burn psychologists and exercise therapists [30]. Since an important part of functional recovery includes returning to work or school, newer additions to the burn team include vocational counselors, recreational therapists, child life specialists, and teachers.

As with any team, leadership is essential. Models for burn center directorship vary depending on location. Burn surgeons should maintain active decision-making responsibility and control of the care of severely burned patients, including the timing and extent of surgical interventions [31]. The burn surgeon may be either a general or plastic surgeon with additional training in burn care, wound management, skin grafting and amputations. Depending on the availability of intensive care facilities, burn surgeons may need advanced training in critical care; an alternate option is inclusion of an intensivist on the burn team. However, a failed model of burn-care delivery is one in which an intensivist manages the patient and consults a surgeon to perform reconstructive surgery after the patient has healed from most of his/her burns [32].

Optimally designed burn centers should focus on issues important to patient-centered care. These issues include the provision of comfortable surroundings for the patient and family, including an option for a family member to stay with the patient; ideally a burn center has rooms with temperature controls that allow warming of rooms to prevent hypothermia [33]. Equally important is the incorporation of safety measures such as infection control policies that facilitate segregation of patients in the face of an outbreak of a multi-drug resistant organism. Inclusion of staff safety equipment such as mechanical patient-lifting aids (to prevent back injuries) will help promote staff retention [34]. Maintenance of a clean facility is paramount for the care of critically ill, immunocompromised burn patients whose risk of infection greatly exceeds that of patients in all types of units due to dysfunction of the first line of defense against infection—the integumentary system.

All burn units should engage in research and/or quality improvement activities; *at a minimum*, this involves collection of patient data and outcomes, and establishment of a burn registry [22]. These minimal activities establish the basis for ongoing quality and process improvement. Reviewing one's own data and outcomes is the only way to ensure delivery of quality burn care.

The massive expansion in scientific knowledge regarding burns results from the concentrated research efforts of many dedicated burn care facilities across the world. Interestingly, 10,500 burn-related articles were published between 1996 and 2006 compared to 11,000 articles in the previous 90 years [22]. The modern burn unit has clearly been the engine for continued advancement of burn care. Also, as burn is considered a subcategory of severe trauma, burn research has contributed substantially to other areas of trauma, critical

care, and immunologic disease [22]. Establishment of a research arm and dedicated financial support for research endeavors is a hallmark of a mature burn center.

2.2.1. *Balance of benefits and harms*

In HIC improvement in mortality rates after burns no longer seems to be the benchmark of ongoing quality improvement. Optimizing reintegration into family and society after burn is now the meter-stick of progress. In RLS there is still room to improve mortality rates. However, an enlightened approach would be one in which a concurrent focus on reintegration (through a focus on rehabilitation) was embraced.

2.2.2. *Values and preferences*

In RLS, an emphasis must be placed on investment in essential burn care providers and in the facility itself. At a minimum, essential burn care providers (burn surgeons, nurses, and physical and occupational therapists) are crucial to provide a modicum of optimal burn care. Middle-income countries might expand this complement and add desirable providers as discussed above. In RLS, a facility with World Health Organization (WHO)-acceptable body substance isolation (BSI) and sanitation standards is achievable even in countries with a per capita income of less than $5.00 (USD) per day [35].

The availability of dressings, surgical equipment, topical antimicrobials, intravenous resuscitation fluids, and skin substitutes will vary greatly among RLS. Development of locally adapted approaches to care may be a practical necessity, but all settings must adhere fundamentally to the concepts put forth in the entirety of these practice guidelines. However, even in a RLS, attention to burn team organization and commitment to quality of care for the burn patient should result in improved outcomes.

2.2.3. *Costs*

The costs of front-end integrated acute and long-term rehabilitation are challenging for RLS. However, there is an enormously favorable effect in economizing the total cost of care downstream after burn. This is especially evident when authorities factor in the impact on GDP of lost worker productivity, magnified by chronic disability expenses/burdens upon society.

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3. Initial assessment and stabilization

Recommendation 1

Thermally injured patients should be evaluated using a systematic approach that first seeks to identify the greatest threat(s) to life.

3.1. *Considerations in formulating Recommendation 1*

The initial evaluation of burn patients should be performed using a systematic approach such as those described in the course materials of Advanced Burn Life Support (ABLS) and

Emergency Management of Severe Burns (EMSB) [36,37]. These approaches involve methodical evaluation of burn patients using a *primary* and a *secondary* survey, with a subsequent definitive care plan that addresses consultation and transport. Improved physician response has been demonstrated following implementation of a similar standardized and systematic approach to trauma patients [38–40].

3.2. Primary survey

Immediate evaluation for each burn patient starts with the primary survey [36,41], which comprises the following steps.

- **A**irway management
- **B**reathing and ventilation
- **C**irculation and cardiac status
- **D**isability, neurologic deficit and gross deformity
- **E**xposure (completely disrobe the patient, examine for associated injuries and maintain a warm environment)

3.2.1. Airway management

Protecting the airway of a thermally injured patient is an utmost priority (see also, Smoke Inhalation Injury, page 11). Circumstances surrounding the patient's injury can be indicative of the potential for inhalation injury and airway compromise. Early intubation is indicated in patients with symptomatic inhalation injury, or any thermal injury to the face, mouth or oropharynx that threatens airway patency [42]. Fires in an enclosed space or fires that involve use of accelerants or other chemicals predispose patients to inhalation injury.

Airway injury includes (1) supraglottic injury, which typically results in edema from direct thermal insult, and (2) subglottic injury with parenchymal injury due to involvement of toxic gases or soot [43]. Clinical findings that warrant further evaluation for airway compromise include singed facial hair, carbonaceous sputum, soot in or around the mouth, hoarseness, stridor, increased work of breathing, and inability to tolerate secretions [40,42]. Upper airway obstruction occurs in 20–33% of hospitalized thermally injured patients with inhalation injury [43]. Management of airway compromise can include a jaw-thrust maneuver, chin lift, oral airway device, endotracheal intubation, or a surgical airway solution; the most experienced clinician in airway management should secure a definitive airway.

3.2.2. Breathing and ventilation

Once the airway is secure, breathing assessment follows (see also, Smoke Inhalation Injury, page 11). The initial responder should auscultate bilateral breath sounds and determine respiratory rate and depth of respiration to evaluate the patient's ability to adequately ventilate and oxygenate, thus assessing the status of the lungs, chest wall and diaphragm. Specific to burns, identification of circumferential burns of the trunk or neck that may impair respirations is indicated at this time as well, and treatment is the performance of a rapid bedside escharotomy [42].

3.2.3. Circulation and cardiac status

Upon presentation, patients with major burns should be placed on a cardiac monitor and a continuous pulse oximeter, and should undergo blood pressure evaluation (see also, Burn Shock Resuscitation, page 16; and Escharotomy and Fasciotomy in Burn Care, page 18). Blood pressure, heart rate and clinical assessment of unburned skin color are parameters utilized to assess circulatory status. Due to increased catecholamine response following a thermal injury, 100–120 heart beats per minute is considered within normal limits; [36] a higher heart rate should raise suspicion for hypovolemia, other trauma and inadequate pain management. Peripheral, central and intraosseous routes are available for access and may safely be placed through burned tissue if necessary [41].

Fluid management based on weight and burn size should be addressed once further assessment of burns has been established [44,45]. Administration of fluid boluses is unnecessary unless hypotension or other signs of hypovolemia are present. Bolus administration leads to further exacerbation of edema formation and should be avoided unless indicated.

An intact gastrointestinal tract can serve as a conduit for fluid resuscitation. A significant number of burn patients who undergo oral resuscitation for large burns experience vomiting. Enteral resuscitation is an option if resources are limited; however, oral resuscitation is more feasible for burns smaller than 30% TBSA [44] (see also, Burn Shock Resuscitation, page 16). Complete circulatory assessment requires evaluation of perfusion of all extremities, paying particular attention to any circumferentially burned extremities. Compromised perfusion can be secondary to the formation of a tourniquet effect by the non-expandable eschar. Vascular compromise must be identified and treated prior to loss of distal pulses, which is a late finding. If compromised, escharotomy is indicated. This procedure should be performed by a qualified surgeon to re-establish adequate perfusion.

3.2.4. Disability, deficit and deformity

Patients who have sustained a thermal injury often present without altered mental status. However, the possibility of associated injury, substance use, hypoxia, inhalation injury or a pre-existing condition should always be addressed as part of the history of the event. Patient mental status can be easily evaluated via the Glasgow Coma Scale (GCS), which utilizes verbal, motor and eye measurements to establish a baseline mental status on trauma patients [42].

3.2.5. Exposure

Providing adequate environmental control is key for this subset of patients as they have lost their ability to thermoregulate. The patient must be completely exposed to assess for injury and to remove any contaminants that might prolong contact with chemicals or heat sources. Removing clothing early in the evaluation process stops the burning process; all diapers, jewelry, contact lenses, and other accessories should be removed to prevent a tourniquet effect [42]. A warmed environment and readily available clean blankets can prevent or limit hypothermia during the examination process. Thermal injuries can be cooled with cool, not cold, water for approximately 3–5 min [36]. Ice and cold water should be avoided, as they cause hypothermia, can thus complicate

long-term burn management by further conversion of the burn, and may lead to coagulopathy, cardiac arrhythmias and death [42]. Pediatric patients are particularly susceptible to hypothermia and will need increased active warming efforts [41].

3.3. Secondary survey

Thorough examination for non-burn related life-threatening injuries occurs at the secondary survey and is prioritized prior to addressing thermal injury. Indicated imaging, laboratory analyses and adjunctive measures such as urethral catheters, nasogastric tubes, etc. should be completed at this time. Once these steps are complete, a thorough assessment of thermal injury may ensue.

3.3.1. Balance of benefits and harms

This systematic process, as first described for the initial evaluation and treatment of trauma patients, encourages a simplified and methodical approach to identify those injuries most likely to cause death in the first 24 h after burn. This approach emphasizes a pragmatic process for rapidly and accurately diagnosing potentially life-threatening problems, focusing on the precise magnitude of the severity of injury, without inefficient expenditure of time and resources. For example, it is more important to conclude that the patient has smoke inhalation injury and needs to be intubated rather than waiting for analysis of carbon monoxide levels by blood gas analysis. The risk is that some patients may be treated excessively out of proportion to the true severity of their injuries. For example, some patients may be intubated but would otherwise recover without airway protection and ventilator support, and some patients with 30% TBSA burns can be resuscitated orally without excessive intravenous fluids. However, the converse hazard is that critical injuries will be underappreciated, resulting in loss of airway patency, or respiratory or circulatory failure.

3.3.2. Values and preferences

In resource-limited settings (RLS) there is no established universal protocol for evaluation of thermally injured patients, yet it is estimated that over 95% of fatal fire-related burns occur in low- and middle-income countries (LMIC) [46]. Despite the widespread occurrence of thermal injury in these settings, one third to one half of those injured do not seek treatment at a facility; a lack of centers of excellence also limits management [46]. In RLS, therefore, it is important to provide training and education to health care workers at basic-level facilities to reduce the incidence of unnecessary deaths from inadequately treated burns [47].

3.3.3. Costs

Two significant barriers exist when implementing a standardized assessment for burn patients: cost and the ability to disseminate information. In RLS, allocation of funding may be better prioritized for resources more desperately needed for patient care. The ability to disseminate this information is difficult. In resource-abundant countries, courses are offered on a fairly regular basis, and telecommunication and podcasting courses are also options. In these settings, the administrative decision to pursue further education in the initial assessment of burn patients would be a necessary focus for quality improvement.

Recommendation 2

Evaluation of burn should estimate total body surface area (TBSA) utilizing a standardized method and delineate characteristics that require immediate attention from a designated burn center.

3.4. Considerations in formulating Recommendation 2

Although the full extent of the thermal injury is assessed in precise detail during the secondary survey, an estimate of burn size and depth is needed during the primary survey to understand requirements for circulatory support. Patients in the extremes of age should be given special attention as their skin is thin and more susceptible to more extensive injury from lesser thermal insults [42].

Determining the extent of burn is commonly estimated using the Rule of Nines [48]. This rule is based on the concept of dividing the adult body area into anatomic regions, which are represented by nine percent, or a multiple of nine, to calculate the TBSA. If only a portion of an anatomic region is burned, then further evaluation to determine the exact percentage burned is necessary. In infants and children, burn size is modified secondary to the disproportionate body surface area of the head and lower extremities and this is accounted for using the Lund-Browder chart [49]. Using the size of the patient's palm, including the fingers, can act as an approximation as one percent TBSA and can be used as a guideline for estimating burn size [50]. Computerized methods have evolved and demonstrate high correlation and reproducibility that also facilitates the use of telemedicine [51].

Once the primary and secondary surveys have ensured stabilization of the thermally injured patient, transfer to a facility capable of providing the care necessary to support a burn patient is initiated if indicated. Patients who should be referred to a higher level of care for burns include those with partial thickness (second degree) burns greater than 10% TBSA; those with burns of the face, hands, feet, genitals, perineum, or across major joints; and those with full thickness (third degree) burns of any size [52].

3.4.1. Balance of benefits and harms

Larger burns require increased resuscitation due to systemic effects, thus emphasizing the importance of being able to accurately and efficiently estimate burn size. It is also clear that burn patients have improved outcomes if treated in a facility capable of providing an advanced level of burn care [47]. Therefore, it is important to accurately identify those patients with burns severe enough to merit transfer so that outcomes will be optimized. However, transfer to burn centers can cause significant strain on patients and their support systems. Patients may become isolated secondary to transfer. If patients are fortunate enough to have family accompany them, financial and emotional strain are still contributing factors to the status of both the patient and their support system.

3.4.2. *Values and preferences*

Hospitalized patients in RLS often rely on family members for assistance during their hospitalization, for example to provide meals. Families play an integral part of care for hospitalized patients in this setting and transfer to distant locations could jeopardize the quality of care for some patients.

3.4.3. *Costs*

Implementing standardized education regarding burn size measurement is a costly undertaking and requires commitment by hospitals and ministries of health. In addition, transport costs for patients would be significant, as the number of burn centers worldwide is small and is even smaller in settings with limited resources. However, the cost of inadequate care is reflected in loss of life or function, placing greater burdens on families and communities. Future development of applications (apps) for smartphones may provide a cost-effective alternative for practitioners in RLS.

Recommendation 3

Appropriate resuscitation should be initiated promptly and tailored based on patient parameters to avoid over- and under-resuscitation.

3.5. *Considerations in formulating Recommendation 3*

Patients sustaining burns greater than 20% TBSA demonstrate an increased capillary permeability that results in decreased intravascular volume, particularly in the first 24 h following injury [53]. Resuscitation is aimed at providing adequate perfusion while using the smallest allotment of fluid possible to avoid over-resuscitation and its sequelae.

Both over- and under-resuscitation are physiologically detrimental to the thermally injured patient. Over-resuscitation can result in compartment syndrome of the extremities and abdomen as well as acute respiratory distress, while under-resuscitation can further perpetuate burn shock and lead to organ failure [44,53]. Resuscitation can be given orally or via intravenous fluid. Patients with burns of less than 30% TBSA are candidates for oral resuscitation; however, early oral intake can be used to offset intravenous resuscitation volume requirements for patients with larger burns [44].

Multiple resuscitation formulas are utilized to guide burn resuscitation and include, but are not limited to, the Parkland and modified Brooke formulas. Recommendations for use of lactated Ringer's solution with all these formulas range from 2 to 4 mL/kg/% burn over a 24-hour period [53]. All the formulas guide resuscitation with the goal of titrating fluids to obtain a urine output of 0.3–0.5 mL/kg/h in adults and 1.0 mL/kg/h in children [44,53]. Resuscitation formulas serve merely as a guide and patients are resuscitated based on their physiologic needs, not solely from numbers dictated by a formula. Formula instructions further recommend that pediatric patients require more fluid for burns comparable to those of adults due to the increase in body surface area-to-weight ratio [44]. Maintenance fluids, including a source of glucose, should be added to pediatric patient resuscitation fluid as hepatic glycogen stores will be depleted after 12–14 h of fasting [44]. Certain subtypes of patients, including those with inhalation injuries, electrical burns and delayed resuscitation, have been shown to demonstrate additional fluid needs [54]. Delayed resuscitation further propagates the complications of under-resuscitation; the importance of early initiation of tailored resuscitation is thus emphasized.

3.5.1. *Balance of benefits and harms*

Evidence consistently demonstrates that patients suffering significant (>20%) burn size incur a systemic response to their injury that leads to a state of burn shock. The benefit of early resuscitation initiation is paramount and aids in prevention of hypoperfusion, renal failure and death. Nonetheless, continuation of unchecked fluid resuscitation can lead to catastrophic complications, such as airway compromise, edema of extremities leading to a tourniquet effect requiring escharotomy, and abdominal compartment syndrome leading to multiple organ failure requiring exploratory laparotomy and pulmonary complications.

3.5.2. *Values and preferences*

Facilities in RLS may only have the option of oral resuscitation because intravenous resuscitation fluid may be limited. However, intravenous resuscitation is a reliable approach to decrease hypoperfusion and has the additional advantage of not requiring patient cooperation or gastrointestinal tolerance to be effective.

3.5.3. *Costs*

Administration of intravenous resuscitation in RLS can be limited by access to medical facilities capable of aggressive fluid resuscitation. Peripheral or central intravenous or intraosseous access may be limited for similar reasons. Resource-abundant settings typically initiate ongoing evaluation and management of patients with large burns in an intensive care unit with monitors, invasive devices such as urethral and central venous catheters, and a low ratio of patients to nursing staff. Overcoming the cost of aggressive resuscitation in RLS is daunting. Oral resuscitation could be implemented when tolerated by patients to aid in offsetting cost.

Recommendation 4

Tetanus immunization status should be evaluated and addressed if indicated.

3.6. *Considerations in formulating Recommendation 4*

Burn wounds can harbor bacteria and are particularly known to be tetanus prone. Vaccination for *Clostridium tetani* was first established in 1897 and has since evolved to include a tetanus toxoid (TT) and is used widely [55]. The US Centers for Disease Control and Prevention (CDC) have established recommendations for routine vaccination that includes three doses of TT and booster dosing every subsequent decade. Patients who are current with vaccination status require no further treatment. Burn patients with unknown or inadequate vaccination status should receive TT in addition to tetanus immune globulin

(TIG). Intravenous immune globulin may be used as an alternative if TIG is unavailable [55].

3.6.1. *Balance of benefits and harms*

There is great benefit to administration of TT and TIG in the acute management of a burn. Prevention of a life-threatening tetanus infection is easily achieved with vaccination. Minimal risk accompanies vaccination and the benefit-to-harm ratio is heavily weighted toward the benefit.

3.6.2. *Values and preferences*

Vaccinations have gained widespread acceptance. However, recent concerns regarding complications following administration have caused numerous parents to opt out of vaccinating their children. Respectfully informing patients and their families of the potential risk of tetanus infection following a thermal injury and recommending appropriate intervention is key. Additionally, some regions of the world such as Nigeria and Pakistan are experiencing significant social resistance to vaccinations [56].

3.6.3. *Costs*

Although tetanus vaccination in the US ranges from US$14.20–42.61, global programs for childhood immunization have brought the price even in RLS to $0.20 [55,57]. Basic health care providers throughout the world, even in RLS, should have access to TT; TIG may be more expensive and less available. Again, to ensure the avoidance of unnecessary tetanus infections complicating burns, emphasis must be placed on adequate vaccination for all.

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4. Smoke inhalation injury: Diagnosis and treatment

Recommendation 1

Initial assessment of the burn patient should include evaluation of the airway and breathing.

4.1. *Considerations in formulating Recommendation 1*

As respiratory failure is immediately life threatening, including an evaluation of the airway and breathing in the initial assessment of any trauma patient is unarguable. Assessment of the airway and breathing are universally advocated by life support training programs as the first steps in assessment of trauma cases [58–60]. Oropharyngeal burns can rapidly cause obstruction, and other causes of critical respiratory failure, such as coma, require immediate diagnosis and treatment.

4.1.1. *Balance of benefits and harms*

Loss of upper airway patency due to progressive edema from inhaled hot gases will lead to death if insufficient cross-sectional area of the trachea and larynx is available for respiratory exchange. Similarly, the progression of damaged lung parenchyma to respiratory distress syndrome following exposure to inhaled toxicants will result in pneumonia or death. Respiratory injury is the major cause of death in patients injured in structure fires [61].

4.1.2. *Values and preferences*

Decentralization of care throughout many countries of the world, especially in RLS, means that the frequency with which patients may present with smoke inhalation injury may be quite low in rural areas. Recognition of inhalation injury presupposes the existence of resources for providing appropriate treatment. In some cases, humidified supplemental oxygen will be sufficient supportive care until upper airway edema subsides, but the need for endotracheal intubation and ventilatory support may exceed the capabilities of all but a few speciality hospitals in RLS.

4.1.3. *Costs*

Evaluation of airway and breathing require only education of health care providers; there is no need for specialized equipment or supplies. In addition, evaluation of airway and breathing is a standard item in all trauma care educational programs. Therefore, no additional costs are envisaged by inclusion of airway and breathing in the initial assessment of burn patients.

Recommendation 2

Diagnosis of inhalation injury is suspected by a history of exposure within a closed space to products of incomplete combustion, in the physical examination by diminished consciousness, and by the presence of soot in the oral cavity and by facial burns. Normal oxygenation or chest radiographs do not exclude the diagnosis. However, signs such as hoarseness, carbonaceous sputum, wheeze, and dyspnea are strongly suggestive of inhalation injury.

4.2. *Considerations in formulating Recommendation 2*

Evidence for this recommendation is weak, not least because the definition of inhalation injury is imprecise. The term ''inhalation injury'' comprises three main components, which can occur separately but which frequently present in combination. These components are:

1. Systemic poisoning due to the inhalation of gases produced by combustion, such as carbon monoxide (CO) and hydrogen cyanide (HCN).
2. Obstruction of the upper airways due to the effects of heat and subsequent edema.
3. Injury to the lower respiratory system due to the inhalation of noxious chemicals and particulates present in smoke.

As each type of injury is potentially fatal, inhalation injury should be suspected if the presenting history, symptoms or signs suggest the possibility.

Carbon monoxide poisoning is suggested by diminished consciousness together with a history of exposure to fire in an enclosed space. *Hydrogen cyanide poisoning*, which may also be present, produces similar signs. The differential diagnosis includes diminished consciousness from other causes, especially inebriation from alcohol and other drugs, which may have a similar presentation. (The eventuality that a fire may be caused by a prior deterioration of consciousness should also be considered.) Diagnosis of carbon monoxide poisoning is confirmed by measurement of blood carboxyhemoglobin (COHb), which should be performed in all patients in whom inhalation injury is suspected.

Obstruction of the upper airway: In burns to the face, assessment of potential obstruction by edema of the upper airway is more problematic and requires insight into burn wound pathology. Evidence of burning within the buccal cavity (e.g., blistering of the mucosal membrane), or symptoms such as hoarseness or stridor suggest that airway obstruction is imminent, warranting rapid intervention to secure airway integrity. A limited superficial burn to the face, such as a scald burn, is less likely to be problematic. Edema formation in the head and neck may be insidious and obstruction can become manifest within up to 24 h or longer post burn. The clinical approach is discussed below.

Smoke inhalation: The presence of soot in the oral cavity is indicative of smoke inhalation. Signs and symptoms such as hoarseness, wheeze, cough, tachypnea, and hypoxemia can be present on admission or may develop within up to 48 h after exposure. The initial chest X-ray is often normal. Diagnosis is generally accepted as positive by the detection of soot in sputum in combination with any of the above findings, or by the observation on bronchoscopy of damaged mucosa below the larynx [62].

4.2.1. *Balance of benefits and harms*

The technique for initial assessment (see Recommendation 1 above) of the patient with suspected inhalation injury is a rapid, sensitive, but non-specific approach to ensuring that patients with potentially life-threatening injuries are identified. Subsequently a more thoughtful and considerate approach to establishing the diagnosis must be carried out because the supportive treatment indicated by a diagnosis of inhalation injury (i.e., endotracheal intubation and ventilatory support) not only introduces the patient the risk of iatrogenic harm, but also requires the expenditure of significant resources. Therefore, the ideal screening tool for inhalation injury would not only be highly sensitive (thus avoiding the loss of life due to missed diagnosis) but also specific, avoiding intubation of patients who do not need to be intubated. For example, singeing of facial or nasal hair, hoarseness, and expectoration of carbonaceous sputum are ''sensitive'' signs because they are present in nearly all patients with inhalation injury, but they are not ''specific'' because many patients with these signs do not have clinically significant inhalation injury. There remains an ongoing dilemma about which patients require early intubation to prevent loss of airway after smoke inhalation.

4.2.2. *Values and preferences*

Fortunately, the diagnosis of CO poisoning can be made definitively by the assay of COHb. However, there is not a

universally accepted standard for the diagnosis of thermal injury to the upper airway or of significant damage to the lower airways. For example, even within resource-abundant settings, there is variation among burn centers on the routine use of fiberoptic bronchoscopy for the initial diagnosis of inhalation injury [63].

4.2.3. *Costs*

The diagnosis of inhalation injury requires considerable skill and experience. Furthermore, diagnosis implies the availability of resources to respond to a positive diagnosis; inhalation injury can only be managed in a well-equipped intensive care unit. COHb measurements can be made with little additional cost to the basic cost of an arterial blood gas analysis. However, if the facility lacks the basic equipment to obtain and analyze arterial blood gases, diagnosis will be made on clinical grounds only. The advantage of proper diagnosis and timely treatment of CO poisoning is the elimination of unnecessary deaths and neuropsychological disability, which reduce the indirect medical costs to the community. Similarly, there are significant costs of providing fiberoptic bronchoscopy, which may be ultimately defrayed in the reduction of unnecessary deaths or prolonged hospital stay. However, even in resource-rich settings, in the great majority of cases diagnosis is made primarily on clinical appearances.

Recommendation 3

Treatment for suspected or confirmed carbon monoxide poisoning is administration of high-flow supplemental oxygen for at least 6 h.

4.3. *Considerations in formulating Recommendation 3*

Although, for obvious reasons, no comparative clinical studies are available, the recommendation is based on well-established principles of pharmacology and physiology. Carbon monoxide is a colorless, odorless gas that is produced by the incomplete combustion of hydrocarbon fuels. CO diffuses rapidly and competitively binds with hemoglobin, displacing oxygen, which results in hypoxemia. The affinity of CO for hemoglobin is approximately 200 times that of oxygen. In addition, CO binds to cytochromes, interfering with cellular oxygen utilization. Hypoxemia caused by CO poisoning is not detected by pulse oximetry or by partial pressure of oxygen (pO_2) measurements.

The COHb binding is stable, with a half-life of up to 4 h in a person breathing air. Increasing the arterial pO_2 accelerates CO displacement from the hemoglobin molecule; administration of 100% oxygen shortens the half-life of COHb to 40–60 min [64]. Therefore, patients suspected of having CO poisoning should immediately be given oxygen, preferably via a non-rebreathing mask, at a rate of 8–15 L/min, depending on mask design. Treatment should be maintained for at least 6 h, or longer if symptoms persist. The indication for intubation and mechanical ventilation is dictated by the level of consciousness.

Hyperbaric oxygen: From theoretical considerations, one would conclude treatment by hyperbaric oxygen would further accelerate elimination of CO, but practical difficulties of monitoring and providing ongoing vital care preclude this mode of treatment in most instances. A systematic review of hyperbaric oxygen treatment found insufficient evidence to recommend its use [65].

Hydrogen cyanide (HCN) is released by the combustion of nitrogen-containing compounds, which are present in plastics, fabrics and paper. Cyanide interferes with intracellular oxygenation, principally by inhibition of cytochrome oxidases. There is substantial evidence that hydrogen cyanide is commonly inhaled by fire victims [66] and may contribute to morbidity and mortality. The half-life of cyanide in man is approximately one hour [66]. Presenting signs and symptoms are similar to those of CO poisoning. Empirical treatment involves administration of high-flow oxygen. Specific antidotes are advocated, especially hydroxocobalamin, which binds to cyanide and is relatively non-toxic; but administration must be immediate for any effect to be useful [67].

4.3.1. *Balance of benefits and harms*

The use of increased levels of inspired oxygen content to reduce the amount of CO bound to Hb is therapy that is presumed to be effective at reducing morbidity and mortality from CO poisoning is a presumption that is not supported by randomized, clinical trials, yet is so theoretically sound that it defies challenge. Similarly, the early effects of the inhalation of smoke on the trachea-bronchial tree result in hypoxia, which again is treated by the administration of oxygen. While there is evidence that the prolonged administration of oxygen at inspired concentrations above 40% may cause parenchymal damage, the use of oxygen as an initial treatment of fire victims is logical and potentially life-saving.

4.3.2. *Values and preferences*

The use of supplemental oxygen in patients extricated from structure fires or exposed to smoke is dependent on provision of this simple therapy throughout pre-hospital and basic hospital systems throughout RLS. The lack of randomized, prospective clinical trials to support this recommendation is likely to remain because it would be unethical to perform a trial in which supplemental oxygen administration would be withheld.

4.3.3. *Costs*

Pre-hospital care systems are either poorly developed or non-existent in RLS, yet provision of supplemental oxygen can be found in many basic hospitals and some clinics. In resource-abundant settings, established pre-hospital care systems routinely provide supplemental oxygen therapy. Where supplemental oxygen is a treatment available for administration, the other critical step is providing health care providers with necessary education so that appropriate patients will be selected for support. The cost of education for this particular modality can be bundled with the other educational activities proposed in these recommendations.

Recommendation 4

Treatment of upper airway burns secondary to smoke inhalation includes observation and monitoring. Patients with upper airway burns should be nursed in the semi-upright position

with moderate elevation of the head and trunk. Endotracheal intubation or tracheostomy is indicated if airway patency is threatened.

4.4. *Considerations in formulating Recommendation 4*

Although evidence supporting this recommendation is weak, the management of upper airway burns with respect to airway patency is a clinical necessity. As edema formation continues for many hours, continuous monitoring and frequent assessment are essential.

Moderate elevation of the head of the bed allows gravity to help reduce airway edema by facilitating venous and lymphatic drainage, and is therefore a sensible, critical standard practice. The patient should be given oxygen by mask to maintain adequate arterial oxygen saturation. Suction should be used to keep the airway clear of debris and secretions.

To protect the airway, the presence of burns inside the oral cavity and the occurrence of stridor are strong indications for immediate intubation. Other signs for concern include tachypnea, hoarseness and the use of accessory respiratory muscles.

Children are at greater risk of obstruction, as are patients whose burns include circumferential burns to the neck. Other early signs and symptoms of respiratory dysfunction may be more suggestive of smoke inhalation. These signs include a ''brassy'' cough, wheezing and breathlessness. Arterial oxygen desaturation despite oxygen therapy by mask is an important marker of respiratory compromise.

In many cases of upper airway burns, it is prudent to observe and hold off on immediate intervention. On the other hand, failure to intervene presents a risk of airway obstruction later as edema develops. If delayed, laryngoscopy and intubation may be hazardous, due to the presence of pharyngeal edema. The clinical decision to intubate in order to protect the airway depends on the availability of technical expertise and facilities and, above all, on the clinical insight of the physician in charge. The decision is often facilitated by the presence or absence of significant smoke inhalation, which requires mechanical ventilation to maintain adequate gas exchange.

No evidence supports the use of tracheostomy in burn patients. In a recent survey of American burn centers, tracheostomies were most frequently performed at 2 weeks, but most respondents agreed that early tracheostomy was indicated under certain circumstances [68]. Indications cited included predicted need for prolonged mechanical ventilation, burns of head and neck, and failure to wean. The conventional surgical procedure was preferred to the percutaneous method, especially in the presence of neck burns. In all cases requiring intubation, meticulous hygiene of the oropharynx and trachea are mandatory to prevent the occurrence of ventilator-associated pneumonia (VAP).

4.4.1. *Balance of benefits and harms*

This recommendation describes the best practice of care for patients with inhalation injury. Although not supported by prospective, randomized, clinical trials, this recommendation summarizes the consensus of experienced burn clinicians, both nurses and doctors. As such, this practice of care may be effective at reducing, but not eliminating the complications associated with inhalation injury. However, intubation and ventilation may cause harm. Apart from the obvious risks of accidental extubation and mechanical obstruction, there is growing awareness of the risks of mechanical ventilation itself (see Recommendation 5), patients require increased administration of sedatives and analgesics and are no longer able to maintain homeostasis. Intensive care facilities are then essential for the provision of appropriate fluids and nutrition.

4.4.2. *Values and preferences*

Consistent with support for the recommendations above, education is key to instituting this recommendation into consistent clinical practice. However, barriers to ensuring permanent implementation of these care plans include large volumes of patients, shortage of human resources, and the absence of clinical standards for intensive care.

4.4.3. *Costs*

The resources required for optimal clinical care plans for patients with inhalation injury are high. The provision of intensive care requires investment in human resources, education and facilities and therefore represents a considerable financial commitment. The ability to provide optimal care for patients with inhalation injury is therefore dependent on the availability of expensive intensive care facilities and clinical expertise.

Recommendation 5

In those patients requiring ventilatory support, lung protective strategies should be employed. Prophylactic antibiotics and corticosteroids are not indicated for the treatment of smoke inhalation injury.

4.5. *Considerations in formulating Recommendation 5*

In the past 15 years evidence has accumulated from studies in the intensive care unit (ICU) that positive pressure mechanical ventilation is associated with lung injury (ventilator-associated lung injury, VALI) and acute respiratory distress syndrome (ARDS). It is suggested that damage to small airways and alveoli is caused by the mechanical forces transmitted by cyclical positive inflating pressures [69]. Various studies show improved survival using low tidal volumes in patients with ARDS [70]. For this reason, lung protective strategies, maintaining plateau pressures below 31 cm H_2O and tidal volumes below 7 mL/kg, are being increasingly adopted in the ICU setting [71].

Efforts to apply protective ventilation strategies to burn patients have been problematic [72]. The effect of smoke inhalation on VALI is unknown and thoracic compliance may be affected by burns to the thorax and abdomen. Above all, the hypermetabolic response to burn markedly increases the demand for respiratory gas exchange. A recent survey in North American burn centers found a wide variation of ventilator practices, with reported difficulties in adhering to low tidal volume strategies, suggesting that burn patients on

ventilators may comprise a unique subpopulation [68]. At the present time, while conventional ICU ventilation guidelines may not be pertinent, it nevertheless seems prudent to assume that VALI also occurs in burn patients. Therefore, the use of the lowest possible inflation pressures and tidal volumes, compatible with respiratory demands, is suggested for the mechanical ventilation of burn patients. At the same time, it is acknowledged that the optimal approach to mechanical ventilation in burn patients has yet to be established.

Ventilator-associated pneumonia is common and potentially fatal [73]. Scrupulous hygiene around the head and neck area, including the oropharynx, and regular clearing of the airways under sterile conditions are essential. Measures that help to reduce ventilation requirements include nursing in a semi-upright position and escharotomies as appropriate for burns to the trunk, both of which increase total lung compliance. Empirically, maintenance of optimal fluid balance and other aspects of general burn care, such as nutrition, effective wound coverage and pain control, all reduce the hypermetabolic response, which decreases the respiratory demand.

Corticosteroids are not recommended for the initial treatment of inhalation injury [74]. Humidification of inspired gases helps prevent mucus retention. Mucolytic agents such as acetylcysteine and bronchodilator therapy may be useful adjuncts. Antibiotics have no effect on inhalation injury until infection supervenes, when the choice of antibiotics should be based if possible on the antibiograms of the causative microorganisms.

In conclusion, inhalation injury is a potentially life-threatening condition which can lead to respiratory failure from a number of mechanisms. Recognition of inhalation injury and the subsequent monitoring of vital signs are essential. Initial treatment comprises the administration of oxygen in high concentration. A conservative approach is advocated if clinically appropriate, but intubation and mechanical ventilation may be life-saving. Respiratory support is not a cure, and all measures to promote body homeostasis and wound healing should be aggressively pursued.

4.5.1. *Balance of benefits and harms*

This recommendation is supported by the scientific literature and by expert clinical opinion. Clinical practice that is consistent with this recommendation results in improved outcomes, including fewer complications and reduced mortality. Additionally, this topic is a field in which there are many promising research endeavors currently underway, many of which should help guide improvements in future care.

4.5.2. *Values and preferences*

Endotracheal intubation and mechanical ventilatory support are now more common in RLS, but optimal ventilation requires continuous monitoring and frequent adjustments, posing additional strains on limited resources. Again, education will play a key role in ensuring that these principles will be employed in the care of patients with inhalation injury.

4.5.3. *Costs*

Dissemination of these clinical recommendations is an ongoing responsibility of national, regional and international burn care associations. However, there is an equal responsibility of health care facilities and practitioners to guarantee that management of inhalation injury is an ongoing priority for continuing medical education activities. Thus, as in Recommendation 4 above, there is a considerable logistical challenge to provide the support of hospital administrators and government health officials, as well as the commitment of health care professionals to acquiring and maintaining standards of care in this field.

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5. Burn shock resuscitation

Recommendation 1

Adult patients with burns greater than 20% total burn surface area (TBSA), and pediatric patients with burns greater than 10% TBSA, should be formally resuscitated with salt-containing fluids; requirements should be based on body weight and percentage burn.

5.1. *Considerations in formulating Recommendation 1*

Available evidence identifies fluid resuscitation with salt-containing fluids as a foundational aspect of burn care [75–77].

5.1.1. *Balance of benefits and harms*

Significant agreement from the literature substantiates that resuscitation volumes should be correlated with burn size and patient-weight based; however the fluid composition and the injury threshold at which resuscitation should be instituted does not represent unanimity of opinion.

5.1.2. *Values and preferences*

Health care providers and policymakers from resource limited settings (RLS)—and providers the world over during events involving mass casualties—face a critical challenge, as the cost and availability of properly sterilized intravenous catheters and intravenous salt solutions mean these resources may be unattainable. (See below: recommendation 3 regarding oral rehydration.) Otherwise, the unanimous preference would be to provide this life-saving therapy that so greatly impacts patient pathophysiology downstream.

5.1.3. *Costs*

Costs of intravenous catheters, their sterile introduction and maintenance, and sterilized intravenous salt solutions can be challenging in RLS, depending on the particular scenario. In general, however, use of effective and timely fluid resuscitation is greatly favorable for economizing the total cost of care downstream after burn.

5.1.4. *FAQs*

Q: What are the recommendations describing the lower limit of burn size that is an indication for burn shock resuscitation in infants?

A: No supportive literature substantiates recommendations for infants. However, some experts feel that infant patients with >10% TBSA injuries should receive resuscitation [78].

Q: Are there other factors that might compel clinicians to use resuscitation for smaller TBSA injuries or that indicate an increase in predicted fluid needs?

A: Inhalation injury and exceedingly deep burns (e.g., 4th degree injuries) typically amplify the need for fluid resuscitation.

Q: Can you be more specific about choice of salt-containing fluids?

A: Many experts consider it better to use balanced salt solutions (e.g., lactated Ringer's), which are less acidic and more similar to normal plasma electrolytes, compared with normal saline.

Q: What if there is a several-hour delay after burn? How is resuscitation managed then?

A: Most experts judge that several hours' delay prior to presentation requires an initial accelerated administration of fluids, which would have been earmarked for those hours in transit. Using urine output and other monitoring values of adequate volume status becomes even more critical given this type of additional uncertainty.

Recommendation 2

When IV fluid administration is practical, between 2 and 4 mL/kg body weight/burn surface area (% total body surface area, TBSA) should be administered within the first 24 h after injury, with alertness to over-resuscitation.

5.2. *Considerations in formulating Recommendation 2*

Morbidity and mortality resulting from over-resuscitation must be avoided. The value of employing colloids remains unresolved [79–84].

5.2.1. *Balance of benefits and harms*

The available evidence demonstrates a continuum of effects, both positive and negative, based on the amount of IV fluid administration as a function of weight and burn size. The theoretical objective is to alleviate the post-burn hypovolemia and hypoperfusion by ensuring adequate end organ perfusion. Erring on the side of excessive, gratuitous fluid administration has a converse detrimental effect, sometimes resulting in death. Although such fluid administration is widely practiced, no study has yet been conducted to corroborate extensive empirical conclusions that colloids are in fact an often-critical component of resuscitation from the worst incidences of burn shock.

5.2.2. *Values and preferences*

Given the lack of supporting studies, health care providers and policymakers are likely to allot a low value to the routine use of colloids in burn shock resuscitation. In the end, the treating provider is ultimately responsible for the clinical outcome, and if pragmatism is to prevail, local successful practice patterns (constricted by fiscal realities) must be honored.

5.2.3. *Costs*

Colloids are prohibitively expensive as compared with salt solutions. Cost alone may provide sufficient justification for eliminating colloid use from local standard practice patterns.

5.2.4. FAQs

Q: What are some of the benefits perceived by those experts who choose to include colloids in their burn shock resuscitation practices?

A: Several respected burn experts believe that resuscitation of very large injuries (e.g., >70% TBSA) proceeds much more smoothly with the inclusion of colloids. Others believe that "fluid creep" (very large volumes of salt solutions that can be dangerous and sometimes lethal) is less likely to develop with colloid administration.

Recommendation 3

If only oral fluid administration is practical, drinking liquids (typical of the local diet) equivalent to 15% of the body weight every 24 h is recommended for two days. Five-gram tablets of table salt (or the equivalent) must be ingested for each liter of oral fluids.

5.3. Considerations in formulating Recommendation 3

Class 1 evidence is lacking for the use of oral fluids in resuscitating burn shock patients. Peer-reviewed scholarly articles are greatly needed.

5.3.1. Balance of benefits and harms

Despite the lack of evidence supporting this recommendation, expert opinion encourages the use of oral resuscitation. Especially under circumstances where the alternative is no resuscitation, the promoted benefits are compelling and outsize the potential risks [85–88]. Inadequate resuscitation equates with unnecessary deaths.

5.3.2. Values and preferences

Even in light of a paucity of evidence to inform our determination of benefits or harms, health care providers are likely to reach for oral resuscitation when treating patients with burn shock, and consider it justified in this work, because the alternative is to do nothing in the face of a known potentially lethal pathophysiology.

5.3.3. Costs

The costs of the oral rehydration schemes presented here are trivial, even in RLS.

5.3.4. FAQs

Q: Is this amount of oral fluid tolerable? Will it simply induce vomiting?

A: The few experts with experience using oral fluid resuscitation for burn shock believe that administering frequent, small fluid amounts (50 mL or less each time) is the most sensible way to effectively employ the oral route of fluid administration.

Q: What if salt tablets are not available?

A: Use one level teaspoon of table salt, which is roughly 5 grams.

Q: What are some examples of useable fluids?

A: Multiple fluids indigenous to the setting can be used. Some examples include:

- Rice water (congee) with salt
- Fresh lime water with salt and sugar
- Vegetable or chicken soup with salt
- Lassi (yogurt drink with salt and sugar)
- Sugarcane juice with lemon, black pepper, and salt
- Sports drink (e.g., Gatorade) with ¼ tsp salt and ¼ tsp baking soda for each quart
- Carrot soup with salt
- Gruel (cooked cereal diluted with water) with salt
- World Health Organization UNICEF Oral Rehydration Solution (ORT), used for infectious diarrhea
- Oral fluid formula used for cholera (CeraLyte®90)

Recommendation 4

When practical, monitoring the adequacy of resuscitation can be conducted by titrating salt-containing fluids. For adults, titrate provided fluids to average patients' urine outputs of 0.3–0.5 mL/kg/hour; in children titrate to 1 mL/kg/hour. For the first 3 h of resuscitation, values may still approach anuria, irrespective of the rate of fluid administration.

5.4. Considerations in formulating Recommendation 4

5.4.1. Balance of benefits and harms

Available evidence shows that monitoring the adequacy of burn resuscitation efforts is of great import to outcomes [89–93]. The use of bladder catheters is not practical in RLS and bears potential infectious consequences. The accuracy and applicability of using simpler methods to quantify urine output are not well documented.

5.4.2. Values and preferences

Given the variances of affordability and practicality of urine output monitoring in different settings, policy experts are likely to promote and health care providers are likely to implement such monitoring consonant with available resources and the increased complexity/risk of urinary tract infection.

5.4.3. Costs

Unfortunately, until published studies validate the use of simpler methods to quantify urine output (e.g., weighing diapers), routine bladder catheterization remains a prohibitively expensive luxury that may or may not be attainable in RLS.

5.4.4. FAQs

Q: Isn't monitoring of urine output compulsory and a standard of care?

A: By and large, monitoring of urine output during burn shock resuscitation is the most sensible and reliable method to ensure adequate therapy. However, there may be circumstances geographically and temporally around the globe where it is just not practical.

Q: Aren't these recommended urine outputs rather low?

A: It is true that these values for urine outputs, gleaned from studies and comments in the published literature, are on the low side. A judgment had to be made regarding the chosen set-point of these recommendations, taking into

consideration the relative risk of spawning either inadequate or excessive resuscitation, both of which are highly undesirable.

Q: Can you further clarify the statement in Recommendation 4 that "for the first three hours of resuscitation, values may still approach anuria, irrespective of the rate of fluid administration"?

A: There is often a lag time in human burn shock pathophysiology such that "priming of the pump" cannot be accelerated by more aggressive fluid delivery; a compulsory time factor must be taken into account.

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6. Escharotomy and fasciotomy in burn care

Recommendation 1

Escharotomy should be performed when circumferential or near circumferential eschar of the extremities compromises the underlying tissues or the circulation distal to it. Escharotomy should be performed when eschar on the trunk or neck compromises aeration and breathing.

6.1. *Considerations in formulating Recommendation 1*

No randomized controlled studies have addressed the treatment of extremities or truncal compartment syndromes. Several retrospective or prospective cohort studies have described the frequency of performing escharotomies/fasciotomies in at-risk burn patients [94–99]. Although the exact timing of escharotomy was not mentioned in most of the literature, escharotomy is generally indicated after initiation of fluid therapy. In their series, Piccolo et al. mentioned having performed immediate escharotomies in 11% of cases [100]. Nevertheless, these authors did not address the exact timing of the procedure (before or after resuscitation), time lapse since injury, and cause of injury. Moreover, the article did not specify whether the 11% of cases pertained to the total number of patients treated or the total number of escharotomies performed. The authors noted that escharotomies were performed in 11% of patients at risk (i.e., with deep circumferential extremity burns) immediately after admission. In contrast, another 17% of patients at risk required escharotomy after several hours of resuscitation with intravenous fluids.

Indirect support for the association between initiation of fluid therapy and development of compartment syndrome derives from literature on abdominal compartment syndrome (ACS) in patients without burns. Tuggle et al. conducted a systematic review of ACS and noted that intra-abdominal hypertension was observed only after fluid infusion was begun [101]. Furthermore, these authors observed a correlation between ACS incidence and the volume of the fluid infused. Because of this, patients with large burns (>40% total body surface area, TBSA) are more likely to need escharotomies.

In a systematic review based on fourteen articles and conducted by the Evidence-based Guidelines Group of the

American Burn Association, the authors stated clearly that ''escharotomies rarely are required immediately postburn'' [96]. It is worth noting that all the reviewed references dated from 1958 to 1988.

Conversely, escharotomy is rarely, if ever, required after fluid resuscitation has been completed (i.e., more than 72 h after the burn). The decision to perform escharotomy should be based on clinical findings supported by appropriate invasive or non-invasive monitoring. The first step is to ensure that there are no systemic causes of distal hypoperfusion, such as hypoxia, decreased cardiac output, hypovolemia, or peripheral arterial constriction [95].

Normal capillary filling is a clinical finding with high specificity and negative predictive value. That is, when capillary filling in the nail beds of the extremity at risk shows a brisk return of perfusion within 3 s, there is little likelihood that the burn is restricting blood flow. However, the converse is not true: sluggish capillary filling is not always diagnostic of hypoperfusion secondary to restrictive circumferential burns because there are other systemic causes of hypoperfusion in injured patients. Similarly, Doppler flow signals in the radial, ulnar, posterior tibial, or dorsalis pedis arteries do not normally exclude performing an escharotomy, although progressive weakness or absence of signals is an indication for escharotomy. The presence of distal pulses does not rule out the presence of early compartment syndrome, however, because the amount of pressure required to reduce arteriolar or capillary filling is much less than that required to cease blood flow in the larger arteries.

Pulse oximetry, measuring oxyhemoglobin saturation with simple and inexpensive equipment, may be more helpful for decisions regarding escharotomy because values above 95% suggest adequate distal perfusion, whereas values below 90% indicate a need for escharotomy. Values between 90% and 95% are concerning but require further investigation. (The admonition for the use of pulse oximetry is that carbon monoxide poisoning will falsely elevate the oxyhemoglobin level, leading to a false negative finding.) Direct intra-compartmental pressure measurement, if available, helps in the decision, although it is not available in hospitals in resource-limited settings (RLS). Compartmental pressure below 25 mmHg is associated with adequate tissue perfusion, while pressure above 40 mmHg is an absolute indication for escharotomy. Pressures between 25 and 40 mmHg require clinical correlation with other findings [94–100].

Note: As not all patients at risk (i.e., those with deep circumferential extremity burns) require immediate escharotomy, treatment plans should address minimizing subsequent development of intramuscular hypertension. Such plans should include reducing the volume of fluid resuscitation to what is just required to ensure adequate organ perfusion (typically a urine output of 0.3–0.5 mL/kg/h in adults and 1 mL/kg/h in children) and elevating the affected extremities to reduce edema. Elevation should not be so excessive as to cause traction on the limb; elevate to just above the heart level [94,100].

6.1.1. *Balance of benefits and harms*

The golden rule of escharotomy is to perform the procedure whenever there is doubt as to its need. The risk of complications from unnecessary escharotomy is much lower than the risk of not performing escharotomy when it is indicated. Clinicians commonly make three mistakes related to escharotomies: (1) failing to perform escharotomies when needed, or performing escharotomies with inadequate length and/or depth, resulting in persistent hypoperfusion and subsequent tissue necrosis; (2) extending the incision too deep and thereby damaging underlying functional structures such as nerves or tendons; and (3) performing unnecessary escharotomy in burn skin that eventually heals without grafting, leading to aesthetic impairment due to the unsightly scar caused by the escharotomy incision.

Avoidance of the third mistake is highly desirable, avoidance of the second is essential; but occurrence of the first mistake is disastrous. In cases of doubt, and to avoid unnecessary escharotomies, first elevate the limbs until there may be spontaneous resolution of edema by gravity. If the compromise persists, the escharotomy should be performed [94,100].

6.1.2. *Values and preferences*

An escharotomy is of great value; it might save a life and/or a limb. Preference should always be given to performing the procedure when in doubt, particularly in full thickness circumferential burns. Clearly, it is better to save a patient's life though he/she may live with a severe scar than to lose the limb or the patient in an attempt to avoid scarring.

6.1.3. *Costs*

Particularly in RLS, escharotomy is almost always a bedside procedure. As this procedure is performed without anesthesia, and needs no special equipment or even instruments (maybe cautery in some cases), its cost is negligible. In infants and children, heavy sedation, even anesthesia in occasional cases, might be indicated. Even in these cases, however, the procedure will not take long, making it an inexpensive and cost-effective treatment.

Recommendation 2

Abdominal escharotomy should be performed when circumferential or near-circumferential eschar is associated with evidence of intra-abdominal hypertension (IAH) or signs of abdominal compartment syndrome (ACS).

6.2. *Considerations in formulating Recommendation 2*

Further research is likely to have an important impact on practice decisions, and thus may change the reference points currently used to guide whether to perform surgical release of pressure [94–99,102]. Abdominal compartment syndrome is a serious condition associated with many types of injuries. Burn is a relatively uncommon cause of ACS, and burn patients may develop ACS in the absence of deep burns of the abdominal wall, for example, as a sequela to massive blunt trauma, over-resuscitation, or septic shock [102]. Therefore, the presence of abdominal eschar does not indicate ACS and conversely, the absence of abdominal eschar does not exclude the presence of ACS. This phenomenon suggests that external restriction and

compression by burn eschar plays a minimal role in the development of ACS. Moreover, many burn patients with ACS die despite receiving abdominal escharotomies, which raises questions about the efficacy of escharotomy in treating ACS. The most commonly used method to diagnose ACS is determination of intravesical pressure (IVP) through a catheter inserted in the urinary bladder. The normal range of IVP is below 5 mmHg but it is accepted at up to 12 mmHg in cases of trauma. Values above 25 mmHg necessitate intervention, while values between 12 and 25 mmHg indicate the need for close observation for evaluation [101,102].

Important note: ACS is suspected when there is an unexplained reduction in minute ventilation, oliguria, or both. It should also be suspected not only in patients with major burns but particularly in those who have received an amount of fluid resuscitation well beyond that predicted based on weight and burn size. Ultrasound might help in the diagnosis. In cases where intra-abdominal pressure (IAP), assessed through intra-compartmental needle measurement, is above 25 mmHg, decompression is necessitated via abdominocentesis, laparoscopy or laparotomy [94,100–102].

6.2.1. *Balance of benefits and harms*

The golden rule of escharotomy applies to the abdominal eschar: perform the procedure whenever there is any evidence of increased IAP or ACS. In comparison to procedures involving limbs and the neck, abdominal escharotomy is much safer as no vital structures or vessels pass superficially in the whole trunk. However, a real danger presents itself in cases of very deep eschar where the incision has a far reach, such as to the peritoneum, and when the procedure is performed by an inexperienced person.

6.2.2. *Values and preferences*

Performing escharotomy is always preferred when there are signs of increased IAP. In very deep wounds, an experienced person (general or burn surgeon) should perform the escharotomy. When experienced surgeons are unavailable, escharotomy should be performed with the most experienced person present. Extreme caution should be taken to identify and avoid going too deep into the muscles. When in doubt, stop at the level reached and allot time to inspect the IAP signs and changes. Meanwhile, try to arrange for a burn surgeon or general surgeon to ensure a safe outcome.

6.2.3. *Costs*

Instruments and equipment for measuring IAP or IVP might not be available in most centers. In addition, ultrasound might not be conclusive. Therefore, an easy and applicable way to detect ACS is to insert a venous femoral catheter. In addition to allowing fluid transfusion, catheterization allows monitoring of IAP. Any slowing or interruption of fluid flow in the catheter highly suggests the rise of IAP.

Recommendation 3

Escharotomy should be performed in the longitudinal axes of the affected part near the neurovascular bundles. The extent of the incision in the eschar should range from normal skin to normal skin. If this is not possible, the range should extend from joint above to joint below. The depth of the incision is limited by reaching healthy tissue at the base.

6.4. *Considerations in formulating Recommendation 3*

No clinical trials or well-designed studies have attempted to investigate the quality of evidence surrounding this recommendation; the strength of recommendation is based solely on several case series and expert opinion as well as accepted clinical practice [94–99].

The objective of escharotomy is to break the tourniquet effect of any eschar that affects blood flow. Therefore, it would be most effective to place the release incisions near but not exactly over the affected neurovascular bundles and along their course so that they will be released without being exposed or injured. Limb incisions are therefore longitudinal and in the mid-axial lines (medial and lateral), except in hands and feet where incisions are on the dorsum. Trunk escharotomies might need to be enhanced by transverse incisions in the upper parts of the thorax and abdomen to allow expansion in all axes of both compartments.

To ensure full release, it is recommended that the incision be deep enough to reach a healthy tissue at the base [98]. To ensure decompression, whenever possible, the incision should extend 1 cm in healthy skin or in a superficial burn, proximal and distal to the eschar. If not possible, it is preferable to surpass the incision to the next proximal joint [99]. Veins should be avoided and spared; if impossible, ligation is preferred to ensure bleeding control. No superiority of either scalpel or electrocautery in incision has been noted in the literature [97]. Nevertheless, most guidelines recommend electrocautery because of the ease of controlling bleeding [97,98]. As with all surgical procedures, attention should be given to adequate analgesia and sedation, as well as maintenance of a clean, if not sterile, operative field.

Important note: Monitoring for clinical and investigational indications of escharotomy should be continued hourly for at least 72 h after burn. The most frequent complication is bleeding (subdermal plexus and superficial veins) while the most serious is incomplete release [94,95,99,100].

Injury to deep structures is rare because in most cases the incision should extend to the level of upper subcutaneous fat only and should reach, but not include, the superficial fascia. Evidence of success is the bulging of the subcutaneous fat from the base of the incision, absence of fibrous bands in the incision, profuse exudation of edema fluid from the wound, and disappearance of the clinical and investigational indications [97–100].

6.4.1. *Balance of benefits and harms*

The golden rule of escharotomy is to perform the procedure whenever there is doubt as to its need. The complications of unnecessary escharotomy are far fewer than those of not performing escharotomy when it is indicated. Sticking to the rules minimizes complications. Mid-axial incisions in limbs, and dorsum of hands and feet, make the escharotomy—even very deep ones—a safe procedure.

6.4.2. Values and preferences

Escharotomy is always preferred when its need is in doubt; it is a simple, safe and effective procedure. Nevertheless, improvisation is strictly prohibited; inexperienced staff should never attempt to perform escharotomy as the complications in this case might outweigh the benefit. Therefore, to ensure safe outcomes, the preference is to train all emergency workers to perform escharotomy. In these days of heightened means and timing of communication there is always an opportunity to discuss the decision prior to performing the procedure.

6.4.3. Costs

Apart from patients needing general anesthesia (infants and young children), escharotomy requires no special equipment or even instruments. Even in cases involving infants and young children, however, the procedure will not take long, making it inexpensive and cost-effective.

Recommendation 4

Apart from high-voltage electrical injuries, fasciotomy is rarely indicated as a primary procedure in burns. Fasciotomy is more commonly performed once the diagnosis of compartment syndrome has been confirmed, particularly in cases of very deep burns, whatever their etiologies.

6.5. Considerations in formulating Recommendation 4

No randomized controlled studies of the treatment of extremity human compartment syndromes have been conducted, though several retrospective studies describe the frequency with which escharotomies and fasciotomies have been performed in burn patients at risk [94–96,100].

Fasciotomy is indicated for compartment syndrome. Diagnosis and investigations are similar to those that precede escharotomy. Fasciotomy might be indicated when the clinical and investigational picture of compression persists following escharotomy. Compression of deep structures, such as nerves, may lead to paresthesia. Pain on passive muscle stretching is an indication for fasciotomy. Complications of fasciotomy are the same as those of escharotomy but occur much more commonly, particularly the injury to neurovascular bundles and deeper structures [100].

6.5.1. Balance of benefits and harms

Fasciotomy, in contrast to escharotomy, is a more technically challenging procedure. It requires general anesthesia. As the cuts reach deeper levels of tissue, the risk of all complications, and particularly that of injury to neurovascular bundles, is much higher. This procedure should be performed by experienced burn or general surgeons only. The other real danger is the massive exposure and desiccation of deeper structures, particularly that of the muscles. Therefore, the decision to perform fasciotomy should be arrived at cautiously and preferably supported by investigational hard evidence.

6.5.2. Values and preferences

The decision to perform fasciotomy should always be made cautiously, particularly in cases of non-electric burns. Escharotomy alone should be performed initially; when this fails to achieve intended outcomes, fasciotomy should be done without much hesitation if the compression picture persists. In cases of electric burn, particularly when muscular necrosis is evident, fasciotomy has another advantage: direct inspection of muscles for early excision of the necrotic tissue, thus preventing acute renal failure, infection, and further limb loss [94]. Therefore, there is no role for closed fasciotomies in burns; all the fasciotomies should be open and open fasciotomy should be seriously considered in cases of high voltage electric burns.

6.5.3. Costs

Compared to escharotomy, fasciotomy is more expensive, as it requires general anesthesia, and postoperative care of the wound is more demanding. Moreover, reconstruction after fasciotomy is far more demanding. Nevertheless, though the total cost of fasciotomy is much higher than that of escharotomy, it is far and away the better option cost-wise given the risks and costs of a lost limb.

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7. Wound care

Recommendation 1

Superficial partial thickness burns and donor sites of split-thickness skin grafts benefit from occlusion for long periods (at least one week). Humid and heat-preserving dressings are preferred. If these are not available, moist dressings should be used.

7.1. *Considerations in formulating Recommendation 1*

According to the current medical literature, no ideal dressing—one that would adapt to all wounds at all times—has yet been identified [103–108]. Characteristics of an ideal dressing would be the following:

- Provide an optimum environment for moist wound healing
- Allow gaseous exchange of oxygen, carbon dioxide and water vapor
- Provide thermal insulation
- Impermeable to microorganisms
- Free from particulate contaminants
- Non-adherent
- Safe to use
- Acceptable to the patient
- High absorption properties
- Cost-effective
- Allows monitoring of the wound
- Provide mechanical protection
- Nonflammable
- Sterile
- Available in all settings
- Requires infrequent changes
- Ready to use to reduce dressing time

Modern dressings offer a wide range of choices which adapt to almost all types of wounds. In contrast, classical dressings comply far less with the abovementioned criteria.

To prevent contamination, dryness, and evaporation from the wound as well as to avoid negative mechanical effects, it is wise to leave the dressing on the wound as long as possible, thus providing the best chance for healing. When choosing a dressing, the most important factor is the amount of exudate from the wounds. Therefore, for a graft donor site, where exudate is minimal to moderate, polyurethane, hydrocolloids and hydrogels are more appropriate. On the other hand, the partial thickness burn has moderate to high exudate from wounds, making foams and alginates a better choice. Iodine and silver-based dressings could be used for both types of wound. This is true provided that the burns are fresh and first aid was not done or was done incorrectly. If any inappropriate material was used to cover the burn as first aid—for example, coffee or sand—or the patient presented late, then management might need to be modified.

Management of blisters is a complicated issue. The majority of guidelines and studies referred to above suggested de-roofing of the blister and coverage with biologic or modern dressing, as this was associated with better recovery. Nevertheless, the practice of de-roofing is not supported by scientific evidence.

A systematic review conducted by the Australasian Cochrane Centre on February 22, 2009, and available in the Cochrane, Medline and EMBASE databases, revealed a single research study complying with the study's inclusion and exclusion criteria. That study was conducted by Swain et al. in 1987, and concluded that the rates of infection were significantly less in intact vesicles, while pain was significantly less in evacuated vesicles. What makes this study unreliable is that the authors did not provide details about how the ''exposed'' category was managed. The second questionable issue in this work is that it was conducted before the popularization of the modern dressing, which changed a lot of professional attitudes. Nonetheless, the conclusion could be drawn from this study that small vesicles anywhere on the body are best left alone. This investigation also recommended that blisters in closed spaces, such as the fingertips, even if minor, might be evacuated if they are associated with pain. Similar results were reached by Murphy et al. who found no clear evidence for evacuation of blister fluid [109–112].

One valid advantage of de-roofing blisters is the capability of visualizing and assessing the wound as, in some instances, vesicles might hide a deep dermal burn underneath. Moreover, it is very common that patients present with already sheared blisters, either intentionally or unintentionally [113,114]. Another valid reasoning for de-roofing is that large vesicles impede the mobility and comfort of the patient [115].

As stated by Sargent in the systematic review concerning the management of blisters [116], six factors should be considered in final decisions regarding management of these blisters. These factors are: infection, healing, functional and aesthetic outcome, patient comfort, ease of dressing care, and cost-effectiveness. Still, all the evidence supporting this management plan is based on personal and expert opinion rather than well-structured studies. One important factor is the wall of the vesicle; when thin and likely to rupture, de-roofing or evacuation is the most appropriate choice. As leaving the vesicle intact is not ''inferior'' to de-roofing, in resource-limited settings (RLS), in cases where vesicles are not impending rupture nor impeding movement or dressing (even if they are of considerable size), it is recommended that they be left intact

Tips:
The alternative means of blister management is to snip open the vesicle, evacuate its contents, and leave the walls to drop on the raw area underneath as ''biologic dressing,'' over which an antimicrobial agent is applied followed by a bulky dressing or bandage. This snip-open practice is not used anymore in most centers; since the introduction of modern dressings, it has no advantage over leaving blisters intact or performing de-roofing and has the potential for leading to complications from both techniques. Nevertheless, this method is extremely useful in RLS when the vesicle is of huge size and impedes movement or the application of proper dressing. It is also practical when the vesicle wall is very thin and impending rupture.

In RLS where the modern dressing is not a valid choice, when the vesicle is de-roofed the wound should be dressed using classical dressing and left closed until it is soaked through. This procedure is continued until the achievement of

complete wound healing. When the vesicle is de-roofed, an interface should be applied to the wound, followed by topical antimicrobial cream (water-soluble base) and the wound is then closed with bulky fluffy dressing to ensure as much moisture and sealing as possible. When the dressing is changed, the interface should be left in place, and topical as well as fluffy dressing should be re-applied over and over until complete healing is achieved.

7.1.1. *Balance of benefits and harms*

Theoretically, de-roofing with modern dressing application, when available, seems to be the safest and most convenient choice. This helps to avoid a deep-dermal burn hidden under vesicles, which might cause an esthetic problem. Healing by modern dressings or biologic membranes leads to the best quality of healing. This also allows excellent mobilization of the patient and his/her burned areas.

When modern dressings or biologic membrane is not available, snipping open of blisters seems to be the next best alternative. This shares the advantages of de-roofing in not impeding movement and in reducing pain, and at the same time it gives a ''biologic'' dressing that ensures the best moisture and sealing effects. Applying an antimicrobial cream with interface ensures the prevention of infection and mechanical trauma during fluffy dressing change. The other advantage is that the ooze is not huge due to the presence of the vesicle wall on the wound.

The last and perhaps least convenient method is performing de-roofing with the application of classical dressing. The interface should be wide-pored to allow the ooze to pass to the fluffy dressing, away from the wound surface, and hence reduce the risk of infection as well as delayed healing. Evidently it is expected that the dressing will be soaked far more rapidly than in cases of snipped or intact vesicles. It is therefore recommended to change the dressing after 3–5 days, leaving the interface on the wound surface uninterrupted, to avoid bacterial growth in the dressing. The second and following dressings could be left for a longer duration.

7.1.2. *Values and preferences*

The longer the dressing is left uninterrupted, the less the environment is disturbed, and the more the healing is rapid and of good quality. Similarly, less frequent dressing is of great value to the patient as it reduces suffering, pain and metabolic consequences.

The preference, therefore, that will ensure the best benefit is to leave the dressing as long as possible over the wound. Nevertheless, in cases of dirty or contaminated wounds, it is advisable to change the dressing more frequently. This is particularly advisable when first aid has been performed using the wrong material (such as coffee or sand), or with wounds where the patient presented late (more than 24 h after the accident). In these circumstances, dressings should be changed every other day until the absence of infection is assured and the wound has begun sound healing. In this case, dressing could be left for a longer period until full wound closure.

7.1.3. *Costs*

Infrequent dressing is cost-effective for both the patient and the health system as it decreases the direct and indirect costs of staff time and transportation. It should be encouraged and practiced whenever feasible.

Modern dressings and biologic membranes are the preferred dressing choices as they ensure the best means against infection as well as scar quality outcome.

Particularly in RLS and low- and middle-income countries (LMIC), the snip-open procedure is very valuable and cost-effective. It could be performed safely and effectively as an outpatient procedure in any setting, even in a primary health care facility. Thus patient transportation fees and modern dressing costs are eliminated while allowing infrequent change of fluffy dressing which leads to further cost reduction. The same applies for intact vesicles.

Finally, when the vesicle is destructed or sheared, classical dressing will be the only choice. According to the state of the wound, dressing should be changed at the least possible frequency. Nevertheless, it is advisable to have a second look within 5 days to verify the condition of the wound and the degree of dressing soak.

Recommendation 2

Cleansing with gentle washing is the most important component of burn wound cleansing. The beneficial effect of using antiseptics or antimicrobial agents for cleansing is unclear.

7.2. *Considerations in formulating Recommendation 2*

Wound cleansing is the first step in infection prevention and cure, and essential for sound healing. All systematic reviews conducted to date did not find any significant correlation between the solution used and the rate of infection or healing [117–124]. Even a comparison of various types of water did not reveal any significant differences. Nevertheless, most of the studies might have had some methodologic limitations—particularly the few in which saline or antiseptics were superior to water did not include information regarding how they used these products for wound cleansing and in what frequency.

In a systematic review performed by Cooper et al., three trials mentioned that saline is significantly more advantageous than tap water [125]. Looking through the methodology, saline was used through syringe splash, and the tap water method was not mentioned. In five other studies there was no significant difference between the use of saline and tap water when both were administered through syringe. Two further studies showed no significant differences, but the method of use was not mentioned.

The important factor in cleansing is therefore the method of applying the agent rather than its nature. Mechanical cleansing by irrigation is the factor that was significantly correlated to decreasing the bacterial count in the wound as well as promoting sound healing [126–129].

Even in cases where the swabbing and irrigation did not show a significant difference in terms of wound contamination and healing, patient satisfaction and cost-effectiveness were significantly better with irrigation [130].

Important notes: Cleansing is an important part of wound care. It is a crucial part of infection prevention, healing, and

patient satisfaction. Wound cleansing and care has nine main objectives that should be fulfilled by the end of the procedure. These are to remove: (1) contaminants at the wound bed; (2) debris, (3) foreign bodies, (4) microorganisms in infected wounds, (5) superficial slough, (6) dressing materials, and (7) excess exudate and crusts as well as (8) hyperkeratosis from wound edges and surrounding skin. Last, and definitely not least, an objective of wound cleansing and care is to (9) aid the patient with personal hygiene and comfort. The more that these objectives are successfully met, the greater the chance for a favorable outcome [131,132].

Tips:
Irrigation cleansing could be applied in several ways, and these are chosen according to the resources available at the setting. Similarly, any solution could be used as long as it is sterile or at least decontaminated.

7.2.1. *Balance of benefits and harms*
Cleansing of the wound is an important step in infection prevention and treatment, as well as in initiating sound healing. Irrigation, even if it is as effective as swabbing, has proven to be significantly more satisfactory to patients.

For clean wounds (and most burns are clean), cleansing should be performed as gently as possible to avoid the injury of the lower layers of the epidermis, responsible for regeneration and healing. On the other hand, in heavily contaminated or infected wounds, cleansing should be performed aggressively, thoroughly, and as frequently as possible to eliminate the biofilm.

However, in some instances, when the biofilm is not responding to irrigation, surgical cleansing (debridement) is advised to break the vicious cycle of biofilm-induced infection. Only dead tissue and tight debris are removed. Then irrigation is restarted for another few days and reassessed for possible further surgical cleansing.

The use of tap water is safe and efficacious. In heavily infected wounds with evident biofilm, antiseptics/antimicrobials could be used, as topical and not cleansing agents, after tap water/saline irrigation, to combat the exposed bacteria and organisms that became ''accessible'' after cleansing. Similarly, those agents are used to thoroughly decontaminate the wound after surgical debridement; use of these solutions is valuable in blocking the passage of virulent organisms into the spaces opened by surgical intervention and eventually into the bloodstream.

7.2.2. *Values and preferences*
The act of cleansing should be the rule in all burn wounds. Irrigation should be the technique of preference for wound cleansing. It has a great value to the wound for efficacy in treatment, and to the patient's comfort. As it has not been proven to be superior, using sterile solutions, with or without antiseptics/antimicrobials, is not advised, either exclusively or after use of tap water.

Cleansing with antimicrobials/antiseptics is of great value after mechanical or surgical cleansing as this would prevent the possible passage of the ''denuded'' bacteria to the newly opened spaces and/or bloodstream. It should, therefore, be the preference in such situations.

7.2.3. *Costs*
Tap water should be the rule for burn wounds as it will be more cost-effective than other preparations, even saline. This rule is most important in RLS, where, given the number of patients and the frequency of dressing changes, it would help in significantly reducing the required care of burned patients. Excluding use of antimicrobial and antiseptic solutions would promote the best allocation of resources of the already limited budget. It is important to emphasize that the water should meet the standards of the World Health Organization (WHO) and should be running water, as stored water might not be as effective.

Use of irrigation should be the routine, as it has proven to be the most cost-effective and comfortable to patients. Although advised, it is not essential to use sophisticated equipment for this type of irrigation; a handheld shower head or a thin-walled rubber hose would serve the purpose in most instances.

Recommendation 3
Raw areas should be dressed with a closed technique. Biologic dressings seem to be superior to nonbiologic dressings. Type (temporary or semi-permanent) and frequency of dressing are decided according to the wound condition and availability of these products.

7.3. *Considerations in formulating Recommendation 3*

Raw area, similar to the superficial partial thickness burn and graft donor site, is an area of the body that lacks epithelial covering. Nevertheless, the loss here is of the whole thickness of the epidermis and dermis, thus exposing the deeper tissues, including subcutaneous fat; fascia; muscles and tendons; vessels and nerves; and even as deep as the bones and joints. Therefore, the necessity of avoiding heat and fluid loss is more profound than in superficial burns. Furthermore, the complete loss of barrier makes these areas more prone to contamination and infection. Moreover, the dryness will definitely delay the healing process and intensifies the loss of vitality of the newly formed granulation tissue and extracellular matrix. It is therefore of utmost importance to completely seal these wounds to prevent infection and promote healing [103–107,120,121].

Raw areas are always contaminated due to the absence of the mechanical skin barrier as well as sweat and bacterial commensals, both which inhibit many pathogens. Therefore, cleansing, through pressurized irrigation is of utmost importance to wash away these bacterial contaminants and debris. Cleansing is more important and decisive in raw areas than in fresh burns. In burns, what applies to chronic wounds would largely apply to raw areas. One of the main problems with these raw areas, therefore, is the risk of infection. Infection, which results from the formation of biofilm in these wounds, would prevent sound healing and endanger the life of the patient.

Biofilms are complex structures of microbial-associated cells, embedded in an extracellular matrix, irreversibly attached to a surface. Biofilm starts in a wound by means of

bacterial contamination and colonization. Once established, the outcome depends upon the relationship between biofilm development and the inflammatory host response; starting from local spread of infection up to septicemia [133,134].

This phenomenon explains why antiseptics/antimicrobials are ineffective, particularly in chronic wounds (agents cannot reach the organism in the matrix), and irrigation in these situations is effective (to detach the biofilm from the surface). Low-pressurized irrigation is usually sufficient for most burn wound raw areas. However, some cases might require high-pressurized irrigation. Longstanding, severely devitalized raw areas might need to be treated as other chronic resistant wounds. In this case, more aggressive physical disruption of the biofilm is needed; this is achieved by using mechanical debridement (fibrous pads, curettage) or by reaching the extreme of the spectrum, through sharp debridement, to remove the biofilm. Removal of this biofilm is the essential and critical element for healing in these wounds [135].

It is evident from these facts that wound sealing and moisture, together with combating bacterial colonization, are indispensable for promoting the growth of granulation tissue and for eventual healing.

Almost all studies regarding the choice of the best seal compared either biologic membranes or modern dressings to conventional or no dressing. Results of comparisons of modern dressings to conventional dressings are confusing; no clear evidence, with regard to complete healing or reduction in size, supports the superiority of modern over conventional dressings. Nevertheless, most studies revealed shorter hospital stays and hence more cost-effectiveness with modern dressing. This might be explained by the management of those patients as outpatients due to fewer and easier dressing changes.

Challenges to the design of studies such as these include the tremendous variation in the type of wound, the amount of exudate, and other clinical factors that are difficult to control for in the randomization process. This played an important role in yielding these results which are difficult to reconcile with clinical experience. Patient satisfaction and less pain were the only significant superiorities in all studies [136].

In contrast, amniotic membrane—whether it was used as fresh, lyophilized and/or irradiated—showed superiority in most of the studies compared to conventional dressing, particularly in chronic burn wounds [137–139]. Amniotic membrane was very effective, even with resistant strains like *Pseudomonas*, in areas with scarce blood supply, such as the cornea [140].

Unfortunately, few studies comparing biologic membranes to modern dressings are available, and the limitation of these studies is the use of a single item of both dressings for comparison, rendering the results of limited value. Nevertheless, these studies showed the superiority of the biologic dressings [141,142].

One of the few articles comparing several dressing modalities is the work conducted by Witkowski et al. in 1986. This work demonstrated that biomembranes are superior to other modern dressings. Biomembranes were superior to hydrocolloids (the only modality demonstrating resistance to bacteria) as they possessed active antibacterial activity. The study has two limitations: the first is its age (now 30 years old); the second is its exclusion of silver-containing dressings [143].

The superiority of amniotic membranes, in cases with similar rates of healing, was evident in better scar quality [144]. The main disadvantage of xenograft is the application in clean wounds only, although cross-linking and impregnation with silver ions has been tried to enhance its application in contaminated wounds. Similarly, homografts have the same contraindication, though they showed improvements in healing in non-infected wounds compared with conventional dressings [145,146].

Tips:

In cases of heavily exudating and/or infected wounds, conventional dressing might be the best choice. It has the advantage of being modified to adapt to the wound status on several levels. Regarding the exudate, conventional is the only type of dressing capable of absorbing the huge amount of exudate. Moreover, it could be changed several times according to the degree of soaking, which can be easily detected. The required number of changes is adjusted according to need.

Conventional dressings have the advantage that composition can be modified. For example, they could be used without interface to facilitate mechanical debridement and biofilm removal. They can also be used with different agents (antibiotics, antimicrobials, or enzymatic agents), and with different amounts of fluffy absorbent dressing according to the amount of exudate.

Another modification that can be made with conventional dressings concerns the mode of application. Wet-to-dry mode is used to remove thick biofilm and mechanically debride the wound in minimally or non-exudating wounds [147]. Nevertheless, some authors do not recommend using this mode [148]. When the wound starts to heal, it could be changed via the wet-to-wet technique until the exudate and biofilm is reduced—the stage at which modern dressing or amniotic membrane could be used.

In an effort to avoid heat and water loss of this type of dressing, it can be wrapped in aluminum foil. However, this practice is not supported by evidence. Amniotic membrane, if available in abundance, could also be used, even in heavily infected and/or exudating wounds.

7.3.1. *Balance of benefits and harms*

The main potential harm of using fresh amniotic membrane is the transmission of serious viral infections such as human immunodeficiency virus (HIV) and hepatitis B and C. Even with negative results, the window phase still poses a problem. Furthermore, other diseases might have been transmitted and not yet diagnosed, like early cases of hepatitis C virus. The benefits of amniotic membrane are numerous: it is inexpensive, readily available, and could be used fresh in any quantities, particularly in RLS, where the birth rates are high. Hazards of amniotic membrane could be avoided by use of lyophilization and irradiation; but this will affect the availability and cost.

Homograft and xenografts are not available in Islamic countries due to religious beliefs. Similarly, bovine products pose a problem for Hindus. In addition, homo- and xenografts are only used for clean wounds, and not as dressings on septic and exudating wounds. Therefore, their benefits in this stage are limited.

Conventional dressings seem to have the most benefit for use during the stage of massive exudation and/or infection. Frequent changes allow frequent inspection of the wound, removal of the debris and biofilm, as well as efficient absorption of the huge amounts of exudate. The risk of losing heat and water is recompensed by the benefits. Although supported only anecdotally, wrapping the dressings in aluminum foil might reduce the risks caused by evaporation.

In moderate and minimally exudating wounds and/or infection, modern dressings have the best benefits for protecting the newly formed granulation and combating the bacteria; biologic membranes are equally beneficial.

7.3.2. *Values and preferences*

As a starting point for neglected wounds, conventional dressing has the best value and should be the preferred method until full assessment is made of the exudate and/or infection. When the raw area is known to be moderately exudating with little or no infection, modern dressing is preferred and has the most value.

Amniotic membrane could be used in any wound, the preference should be to lyophilize and irradiated to avoid the risk of infection transmission. However, if follow-up is performed with the mother throughout a sufficient period, fresh membranes could be used.

Xeno- and homografts are costly and do not combat or resist infection and/or exudate. Therefore, their use should be limited to clean healing wounds in an effort to avoid or limit the size of the autograft [145].

7.3.3. *Costs*

Particularly in RLS, fresh amniotic membrane, if the mother is well screened, seems to be the most cost-effective choice for all wounds. If not available, then conventional dressing should be used until the wound is almost clean with minimal exudate—cases in which modern dressings, or preferably processed amniotic membrane should be used. Xeno- or homografts, if available, should be used only in very clean wounds awaiting autografts.

In resource-abundant settings, conventional dressing might also be the best start until evaluation of the raw area state is made. If the first clinical examination indicates moderate exudate and/or infection, then modern dressings or amniotic membrane should be used, as they would be more cost-effective and beneficial for both the wound and the patient.

Homo- and xenografts are of value, particularly in clean small wounds, as they might lead to complete healing. Still, in large wounds, they might reduce the extent of need for autografts. The cost-effectiveness in these cases should be judged individually.

Recommendation 4

A. Closed dressing is the rule for deep partial thickness and full thickness burns.

B. If early excision is not feasible, deep partial and full thickness burns could be dressed by the open technique until eschar separation has begun.

7.4. *Considerations in formulating Recommendation 4*

During the first few hours post burn, wounds are generally sterile or are at the stage of superficial bacterial colonization. By the 4th to 5th day post burn, extensive bacterial involvement of the wound itself is evident. By the end of the first week, the damaged skin is thoroughly permeated by the increased number of organisms and the more virulent organisms begin active invasion of the unburned tissue [103,149–152]. The avascular nature of the burn predisposes the burn site to bacterial invasion by impeding effective delivery of the antibodies' own defenses and preventing systemic antibiotics from penetrating the damaged area [103].

The primary goals of local wound management are the prevention of desiccation of viable tissue and the control of bacteria [153]. If the wound bed is not kept moist, the wound will dry out and a scab will form. This dry scab will not permit the tangential excision and grafting which is the preferred method for treating deep-dermal and full-thickness wounds.

It is of utmost importance to avoid circulatory impairment with the use of tight dressing. This risk of impairment is minimized by applying this non-adherent dressing in successive strips, rather than wrapping it around the wound [154].

The composition of dressing agents varies widely, although the consensus is to use antimicrobial rather than antibiotic creams. In emergency cases, any moist dressing should be applied to the wound, after the first aid, until the arrival of the patient to his/her final destination [152].

If early excision is not feasible, as in RLS, deep partial and full thickness burn eschar could be dressed by the open technique until eschar separation begins. An Internet search reveals that this method has not been listed in the literature since the early 1990s [155], and was even being criticized as early as the 1950s [156]. Nevertheless, due to a lack of resources, several practitioners still use the open technique; hence the weak evidence and the weakness of the recommendation: it is based only on opinion from "few" experts.

Theoretically, bacteria are unable to survive in dryness. Therefore, keeping the wound extremely dry will not allow bacterial proliferation. In addition, this technique will enhance the early separation of the eschar from its bed, by autolysis, in the form of sheets. This "floating" eschar could be removed by cutting away these parts. In addition, blunt dissection—dissection started under the adjacent areas where the eschar is loosely attached to the bed—is stopped upon reaching an area where the eschar is still adherent and cannot be removed by blunt dissection. This technique is known as "piecemeal" debridement [157]. After removal of the eschar, the wound is treated as a raw area and should be dressed by closed technique.

Tips:

Open technique offers great value in some cases, particularly in deep-dermal burns. In cases of facial burns, even full-thickness ones, particularly in children, the open method is ideal in RLS, where anesthesia is not available daily. Even in adults, the open technique was recorded to be of success and results are comparable with the closed technique. It has the advantages of allowing regular monitoring of the wound and is convenient for the patient to allow eating and drinking.

Nevertheless, care should be taken to avoid self-induced trauma by the patient, particularly children who might frequently scrape the wound. For this reason, several preparations have been investigated for use with the open technique: Vaseline-based gauze, antimicrobials, and heparin-based and moisturizing creams [158–161]. The open technique could be similarly used in perineal burns as these wounds are difficult to close, particularly in children [162].

Another option for deep-dermal and full-thickness burns is the semi-open technique. As its name denotes, it is an option mid-way between the open and closed techniques. Here, the topical products are applied to the wound and covered only with gauze with/without bandage. It allows ventilation and minimal thermal, water, and electrolyte losses. Its main advantage is slight minimization of infection risk in circumstances of limited personnel or equipment resources. The semi-open technique could be used for facial and perineal burns as well as posterior burns (where the patient lies in a supine position, with no need for circumferential dressing).

7.4.1. *Balance of benefits and harms*

The main benefit of the closed technique is that the eschar remains soft to allow tangential excision. It also protects the eschar from infection. Moreover, it prolongs the contact of the antimicrobial agent with the eschar and increases its efficacy in preventing desiccation and infection. Another advantage is the prevention of heat and fluid loss from the wound, although not evident in this stage. In contrast, the closed technique prevents autolysis beneath the eschar and therefore delays its spontaneous separation for several weeks.

On the other hand, the open method has the advantage of being convenient where there is a lack of supplies and/or trained staff. In addition, it leads to early spontaneous eschar separation and hence earlier grafting where tangential excision is not available. Nevertheless, the risk of infection, particularly invasive, is high and the patient might experience pain during eschar removal.

The benefits of the semi-open technique are mid-way between both; it has the advantage of lower infection risk and is easier technically, but it has the disadvantages of later eschar separation and the need to apply an antimicrobial more frequently.

7.4.2. *Values and preferences*

The best value of the closed technique is when early tangential excision is planned and, in these cases, it should be the technique of preference to avoid desiccation. Unfortunately, closed technique is not possible in most RLS. When a strategy of early tangential excision is not available, it might be better to avoid this technique.

Open technique is the best and should be the preferred choice in cases of palliation; it economizes time, manpower and supplies. Face and perineum are best dressed by this technique, particularly in children, as the closed technique necessitates general anesthesia. Moreover, soiling is very frequent in these cases which make the closed technique impractical. Nevertheless, if the logistics permit, these areas could be dressed by the closed technique. Where tangential excision is not planned, for whatever reasons, the open technique could be a good choice as it enhances early eschar separation and facilitates piecemeal excision.

The value of the semi-open technique is mid-way between both the open and closed. It appears to be beneficial only in cases of isolated back burns. Nevertheless, it could also be used in areas difficult to dress, such as the face and the perineum. It has no obvious advantage over the open or the closed; this explains why this technique is nearly forgotten and is no longer widely used. Still, the semi-open technique might be a good alternative to the open method where the burn is not so extensive and circumferential.

7.4.3. *Costs*

Particularly in RLS, as well as in palliative care, the open technique seems to offer great value. Although the evidence supporting its use is weak, the open technique might be the only cost-effective method for burn care. This method economizes all resources, including manpower, which justifies its use against all hazards.

Certainly the closed method is the best assurance of infection prevention and preparation of the eschar for tangential excision. Nevertheless, its costs—direct and indirect—cannot be afforded by many centers. Its use where tangential excision is not practiced is of doubtful cost-benefit. However, if circumstances allow, even in these settings, the closed technique might be a good choice to prevent infection and hence it would be a cost-effective procedure.

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Glossary

In general, surgical technique for excision of burn wounds is defined by the timing (early vs. delayed) and the depth (tangential vs. fascial). As well, there is an underlying philosophy that reflects the need to surgically remove eschar before spontaneous separation begins.

Early excision: removal of necrotic tissue (burn eschar) before spontaneous sloughing or invasive infection can occur; although not universally defined, typically within the first few days after injury, and certainly within the first week to 10 days.

Delayed excision: removal of necrotic tissue (burn eschar) before spontaneous sloughing or invasive infection can occur, but after sufficient time has elapsed to determine how much of the burn will heal by secondary intention without need for surgery; although not universally defined, typically after 10 days but before three weeks after injury.

Tangential excision: using a sequential approach where thin slices of necrotic tissue (burn eschar) are progressively removed to viable tissue.

Fascial excision: removal of burn wound and subcutaneous tissue at a pre-determined deep level; typically carried out down to the level of deep fascia.

Late grafting: Grafting of burns after debridement of slough from granulation by a variety of curettage, excision or avulsion techniques, in delayed burn wound management.

8. Surgical management of the burn wound

Recommendation 1

An appropriately trained, prepared and equipped burn team is essential for any center treating serious burn injuries with excisional surgery.

8.1. *Considerations in formulating Recommendation 1*

Debridement and skin grafting surgery is essential for the optimum treatment of most patients with a significant percentage of total body surface area (%TBSA) of deep burns. Considerable benefits can be gained for the patient's course and outcome regardless of whether skin grafting is undertaken early or late after burn injury.

Early excision and grafting has been shown to reduce hospital stay, improve long-term outcome, and be cost-effective [163,164]. Delayed skin grafting has also been found to substantially improve outcomes in comparison to secondary healing of full thickness burns. Expedited and enhanced healing of full thickness wounds by skin grafting results in much faster patient recovery and reduces incidence and severity of contractures. The benefits of skin grafting such full thickness wounds have been so self-evident that a paucity of controlled research provides proof of these benefits.

Delayed skin grafting may either be undertaken after delayed primary burn excision or after conservative sloughing of the burn wound and grafting onto granulation tissue [168]. The latter approach is advantageous in many services where there are very large numbers of severe burns and limited resources. In such situations, early discharge maybe necessary to allow outpatient conservative management of extensive burn wounds after the resuscitation phase is over. Patients may subsequently be re-admitted for grafting [170].

8.1.1. *Balance of benefits and harms*

Early excision and grafting are associated with the highest achieved survival rates in most patient groups. Early excision requires resources that are not widely available in many burn services, and in resource-limited settings (RLS), which are common in low- and middle-income countries (LMIC) [165]. It remains controversial whether early excision and grafting improve outcomes in comparison with a more conservative approach in a RLS, with studies supporting different conclusions [166–168].

8.1.2. Values and preferences

Where resources are limited, a more conservative approach to burn surgery may be indicated. Management of major burns by debridement with dressings and subsequent delayed grafting may be the safest approach. By waiting until sloughing of the eschar has occurred, surgery is kept to a minimal scale, with harvest of the skin grafts being the main surgical intervention. If using a conservative approach, it is crucial for the burn team to emphasize a rigorous approach to dressings and wound care, develop pain management protocols, optimize patients' nutritional intake, and work assiduously to prevent contracturesby means of physical therapy and splinting. (see Wound Care, page 22; Nutrition, page 51; Splinting, page 58).

8.1.3. Costs

In order to undertake safe, efficacious, and cost-effective burn surgery a skilled and appropriately-resourced team is necessary [171]. Optimal resource requirements for burn surgery include the following:

Team: Anesthetists, surgeons, theater nurses—all with appropriate skills and experience; ward medical and nursing staff and monitoring equipment for safe post-operative care; physical therapists; dieticians.

Theater: An operating theater with appropriate environmental control, vital signs monitoring and gases for anesthesia.

Equipment: Skin graft knives, dermatomes, electrocautery, tourniquets, skin graft mesher.

Sterile supplies: Intravenous fluids and administration equipment, dressings, bandages, antiseptics.

Pharmacy: Anesthetics, analgesics, antibiotics, hemostatic agents.

Support: Blood transfusion, and the following services: hematology, biochemistry, microbiology.

Skin banking: Allograft, xenograft, human amniotic membrane, biosynthetic skin substitutes.

Failure to prepare appropriate logistics and expertise before undertaking excision and skin grafting surgery may endanger patients and result in adverse outcomes. Adverse outcomes may also impair development of the burn service because of damage to morale and reputation.

8.1.4. FAQs

Q: How can a burn care service with very limited resources approach acute burn surgery?

A: Development of a skilled skin-grafting team should be a primary goal of any developing burn service in a RLS. When skin graft harvest is undertaken, use of injected and topical vasoconstrictors on burn wounds and donor sites can minimize the need for blood transfusion (see Recommendation 6). Early excision can initially be reserved for relatively small burns of the peripheries, which may be excised under tourniquet and grafted with no significant blood loss if appropriate measures are used (see Recommendation 6). Practice in these techniques may help individuals to develop the skills and confidence required for inclusion on the burn team.

Q: Our burn service greatly lacks equipment and resources. What can we do?

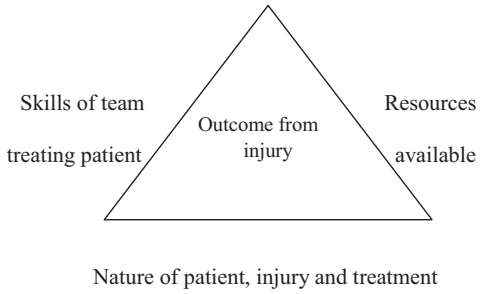

Fig. 1 – Triangle of Care.
Nature of patient, injury and treatment.

A: This is a huge challenge. There is no easy answer to running a burn service in a RLS. Developing a team mentality of improvisation is desirable to repair and recycle existing equipment and to adapt inexpensive locally available materials. Connections with units in high-income countries (HIC) can often provide crucial sources of equipment and support.

Q: How can a burn service in a RLS determine its capability to undertake burn surgery?

A: Interburns® (www.Interburns.org) has developed a set of standards that can guide burn services regarding the levels of expertise and infrastructure suitable for delivery of different models of burn care. A simple model that can be helpful in considering how a service might deal with an individual patient is the ''Triangle of Care'' (Fig. 1). This approach can be applied to determine whether the team and resources available are right for the method of care chosen for a given patient.

Recommendation 2

A. An appropriate surgical plan should be designed for each major burn patient. The plan is determined by: the extent, site and depth of the burn injury; the general physical state of the patient; and the resources of the team treating the patient.

B. Early excision and wound closure is the standard of care where resources permit, but a conservative approach to wound debridement is indicated where logistics and resources are outweighed by patient numbers or available skill sets.

8.2. Considerations in formulating Recommendation 2

In a stable major burn patient with significant deep burns, early burn wound excision and grafting should be targeted at removing as much of the deep burn as possible, with the goal of improving survival. Improved survival has been documented after early excision in a variety of settings [172–176].

The first early excision should be aimed at excision and coverage of a large portion of deep burn, and the largest areas that can be safely excised are chosen. Typically, these would be the front or back of the trunk, or large areas on the limbs. The extent of the burn excised in each operation is determined by the experience and approach of the surgical team, and the availability of autograft donor sites or skin substitutes. If the team is relatively inexperienced and there is little autograft

available, much less %TBSA burn can be safely excised during one surgical episode. After excision, all excised burn area must be covered with autograft skin graft or skin substitute [179,180] (see Recommendation 7).

8.2.1. *Balance of benefits and harms*

Although total early burn wound excision has been shown to be associated with optimal post-burn survival [177], it is likely to be practical only for a minority of major burn patients in most countries. Accordingly, a plan for staged excision, initially excising some of the deep areas that are most straightforward to excise, is likely to be the safe approach in many burn injury services [178].

8.2.2. *Values and preferences*

Availability of resources and expertise are key factors in determining whether early surgery is possible. The sheer number of major burn patients facing many resource-limited units means that early excision is not possible for the majority of patients in many countries [181]. In addition, referral and resuscitation of patients may have been delayed so that they arrive in a physical condition that precludes early surgery. Accordingly, it is often safest to determine a plan for delaying primary excision surgery or skin grafting until after the wounds have desloughed and granulated, and indeed, this is the only possible approach logistically. The approach to a conservative regimen should be as rigorous as possible, with attention given to physical therapy and splinting; nutrition; antiseptic dressings; and fluid/electrolyte balance. The greater the delay before beginning surgical wound closure in a major burn, the greater the risk of complications, especially of mortality from infection.

Patients with an impaired general physical state may be obliged to have conservative treatment: delayed presentation, complicated resuscitation, multi organ failure, age (very young or elderly), and prior medical conditions may preclude early excision because of excessive surgical risk. It should be noted, however, that improved outcomes can be achieved in elderly patients with early surgery [182]. In a major burn patient, planning for skin grafting of key functional and aesthetic areas such as face, neck and hands should be considered about 7 to 14 days after injury [183].

8.2.3. *Costs*

As noted above, the adoption of early excision and grafting as a routine approach for burn care requires the commitment of extensive resources, including supplies, equipment, and trained personnel. Although the initial resource investment may be daunting, the ultimate payoff is the reduction in hospital length of stay (resulting is less utilization of hospital resources) and the need for fewer reconstructive procedures. Aside from these direct benefits to the health care system, the economic benefit to the community resides in the reduction in disability and more rapid return to work or school.

8.2.4. *FAQs*

Q: What is the definition of ‘‘early excision’’ for major burn patients?

A: Consensus has not been reached regarding a precise time period for early excision. Necrotic tissue in deep burn injuries leads to severe illness. The essence of early excision is a proactive surgical approach that removes necrotic tissue from the burn in order to significantly improve the patient’s response to the burn injury, and to reduce complications. The second major goal of early excision is to achieve closure of the burn wound as soon as possible.

In an ideal system, all deep burn could be excised and repaired immediately with no deleterious effects. The history of early excision shows that this is seldom possible, even in a well-resourced service. Timing of early excision is often a balance or compromise involving the physical condition of the patient, the capability of the burns service, and the personal preferences of the clinicians treating the patient. Various approaches described as ‘‘early’’ include the following:

Immediate total excision

In its most radical form, ‘‘early’’ refers to an urgent complete deep burn excision during the first 24 h after injury, as soon as patient and surgical team are ready. This excision is performed during the resuscitation period in order to change the clinical course.

This approach has produced the optimal outcomes for burn survival in massive burns and is the ultimate standard of care for survival after such injuries in young people. Excision at this very early stage has the potential to bring radical improvements in the inflammatory and metabolic response of the patient, and to a great extent, to effect substantial positive change in the patient’s subsequent clinical course.

It is probable that areas of burn of indeterminate depth which might have later healed well may be excised and grafted during this approach. No clear evidence indicates whether this has any positive or negative effect on long-term functional outcome of patients.

Early total excision

Many services use an approach that involves some time preparing the patient to an optimal physical state for an excision of all the deep burn during the first few days. The fundamental difference in approach from the ‘‘immediate’’ is that this excision would occur after the end of the fluid resuscitation period. A common target time would be for this excision to occur within the first 72 h, as there is probably less bleeding from excision sites during this period. However, especially in inhalation injuries and in other situations when a patient is initially systemically unstable, this excision may take place up to a week after injury. In both of the early total excision approaches there is an exception for performing ‘‘total’’ excision: typically, deep facial burns of indeterminate depth would not be excised in the first few days.

Early excision as part of a plan of staged burn excision

This is probably the most widely used approach. As much burn as is deemed prudent is excised at the first surgical excision, with a view to performing further excisions every few days until all the burn is excised. Typically, the first excision will be undertaken within the first 72 h after injury but may be delayed until later in the first week after injury. This approach is ‘‘safe’’ in terms of surgical stress to the patient, but it does increase the period during which the patient can be damaged by systemic inflammatory response from the residual deep burn injury, and the necrotic tissue in the burn wound can be involved by bacterial invasion. Accordingly the benefit of a cautious approach might be

outweighed by the subsequent deleterious effects of systemic inflammation and infection.

Summary

The widest definition of ''early excision'' would be during the first week post-burn, but the later in the first week that the first excision is carried out, the less the direct benefit to the physiology of the patient from the surgery. Excision in the first day can significantly modify the patient response throughout his/her whole recovery.

8.2.5. FAQs

Q: A patient presents late after injury with extensive infected burns, and inadequate resuscitation. How should the burn team proceed?

A: Before excision is carried out, a period of a few days preparation may be best to ensure that dehydration and renal function can be corrected, wounds superficially debrided, microbiology results made available, and systemic antibiotics commenced. A contrary possibility, if the condition of the patient is desperate, is to excise all deep infected burn and wound cover with allograft (or other skin substitute such as amniotic membrane) be performed. Clearly, this would be a high-risk intervention, and risks of uncontrolled bleeding and septicemia would be considerable, but this approach might be life-saving.

Q: How should a burn team decide on the best approach to early excision for their service?

A: The best approach can be chosen by means of service factors and patient factors, as described below.

Burn service factors

Resources will have a strong influence: anesthetic and critical-care expertise, blood products and skin substitutes are extremely important for large early burn excisions. In RLS there are commonly many patients with major burns in comparison to the available resources of the service. In this circumstance, a less radical, staged approach is indicated.

Patient factors

Younger people with full thickness burns, and little or no inhalational injury, are the clearest beneficiaries of a radical early surgery approach.

Patients referred late to the service, poorly resuscitated and with heavily colonized wounds, are seldom candidates for immediate radical surgery because of the greatly increased risks. This is an extremely common scenario in units in RLS. For these patients, a rigorous approach to optimizing resuscitation, renal function, microbiology and metabolism is often necessary for a few days, before surgery may be undertaken.

Patients with major cutaneous burns and smoke inhalation injuries may benefit from early radical surgery, but this benefit is less clear-cut than for ''uncomplicated'' major burns. If the smoke-injured patient is unstable from a systemic point of view, with severe systemic inflammatory response or incipient adult respiratory distress syndrome, it may be better to delay surgery and treat the wounds with an intensive dressing regimen before later surgery when the general condition has stabilized. Decision-making in these circumstances can be very challenging and it is important to elect a combined approach between experienced surgeons and intensivists to determine the best ''window of opportunity'' for surgical excision.

Q: When should one consider excising and skin grafting a deep burn of the face?

A: This is a complex decision, but some of the factors can be summarized fairly simply. Consider excising and skin grafting a deep burn of the face:

- When the diagnosis of a deep burn is reasonably certain. This is usually after about 10 to 14 days for most deep facial burns. After very deep full thickness burns, where the depth is clear-cut at the outset, the face may be grafted earlier.
- When the patient is stable and has already had the major excisions necessary to optimize survival.
- If there is good donor skin available so that outcome of excision and grafting will be better than continuing with conservative treatment;
- If microbiology results are clear of destructive bacteria and coagulation studies are favorable.

In certain circumstances, graft take of excised facial burns may be optimized by placing a temporary skin substitute for 24 to 48 h before definitive cover with autograft or dermal regeneration template. This allows for optimal hemostasis.

Q: When should one excise and graft hand burns in major burn patients?

A: Excision and grafting hand burns should often be performed later than the first major excision is performed; the first major excision of burn in a staged excision should be directed toward excision of large areas of full thickness burn in order to enhance survival (for example, with large areas on limbs or trunk). Because hand burn excisions are more consuming of surgical time and autograft, they produce relatively little beneficial effect on the systemic condition of the patient. Therefore, it is common to leave excision of hand burns until a later staged excision after approximately 6 to 10 days, as long as donor skin is available and the patient is stable.

In massive %TBSA burns, surgery for hand burns may have to be minimized in scale, with an early emphasis on internal (K-wire) splinting, external splinting, and physical therapy. Physical therapy and appropriate positioning of the hand are crucial in preserving function of the hand and speeding recovery of function after major burn injury. Preservation of range of movement of the other joints of the upper limb is also of great importance for handfunction.

Recommendation 3

Early surgery for small- to moderate-sized deep burns (less than approximately 20% TBSA) speeds recovery, might improve outcome, and is cost-effective.

8.3. Considerations in formulating Recommendation 3

Early tangential excision and grafting for deep dermal or full thickness burns has been shown to speed recovery, reduce pain, prevent infection and possibly improve long-term outcome [184,185]. With appropriate measures to prevent

bleeding [186,187], the requirement for blood transfusion and morbidity from blood loss can be minimized (see Recommendation 6). In fit patients, with burns in important functional areas such as hands and feet, early excision and grafting may allow rapid rehabilitation to normal function. Surgery under tourniquet to minimize bleeding, and even with regional rather than general anesthesia, may be possible, and this renders this approach safe in most burn care services.

Hand burns

It is widely accepted that early excision and grafting of deep burns of the hand, with early intensive physical therapy, can produce optimal outcomes in both the short and long term. It must be emphasized that the quality of skin grafts used has a major bearing on the outcome of surgery for hand burns: generally, sheet skin grafts are better than meshed grafts for dorsal hand burns, and full thickness skin grafts are better for deep palmar burns.

Scald injuries

In pediatric scald burns of indeterminate depth, an initial conservative approach has been shown to be superior to aggressive early surgery within the first 72 h [190]. However, an evidence-based treatment goal in scald injuries is to achieve complete healing by 21 days after injury, as it has been shown that there is a significantly increased risk of hypertrophic scarring in injuries taking longer than 21 days to heal [191]. Accordingly, if a unit's resources permit, it is sensible to design treatment protocols that aim to achieve grafting of deep scald injuries by 14 days after injury at the latest, in order to achieve the optimal long-term outcome.

8.3.1. *Balance of benefits and harms*

Conservative therapy with delayed grafting may achieve acceptable results provided there is proper physiotherapy and splinting. Indeed, studies comparing long-term outcome after early or delayed surgery for hand burns have shown conflicting results, with no clear outcome advantage for early surgery [188,189]. It has thus far proved difficult to design studies that definitively clarify this issue, and although many professionals favor an early excision approach, there remains significant controversy as to what leads to ideal results.

A secondary benefit of an early surgery policy on small- and moderate -sized burns accrues because operating regularly on smaller burns improves the skills of the surgical team in treating major burn injuries, for which there is a clear outcome advantage in terms of survival and duration of illness.

8.3.2. *Values and preferences*

In a RLS, small- and moderate-sized burns that are clearly full-thickness should be grafted, particularly where excision and grafting will clearly speed recovery and improve outcome by preventing disability; full thickness burns of the extremities, or over joints, would be a priority. Burns of the extremities can also be treated under tourniquet and readily elevated and immobilized postoperatively so that blood loss can be prevented and graft take is likely to be good.

8.3.3. *Costs*

As noted previously, the routine practice of early excision and grafting can reduce both direct and indirect medical costs. This is particularly true of smaller burns. It is important to remember that the disability associated with recovery from burns is not directly correlated with the size of the burn. That is, even small burns can cause lifelong handicap, especially those on functionally important areas such as the face, hands and feet. Thus reduction of scarring and subsequent immobility by early excision and grafting will have an enormous impact on reduction of disability. The incorporation into practice of early excision and grafting of small- and moderate-sized burns can be achieved with an acceptable increase in resource utilization.

8.3.4. *FAQs*

Q: How can a deep partial thickness burn be differentiated from a more superficial burn early after an injury?

A: The standard of care for accurate diagnosis of a deep partial thickness (deep dermal) burn early after an injury is the laser Doppler scanner. However, this is an expensive item of equipment, and general anesthesia is often required for the investigation in children. Early clinical assessment of partial thickness burns is based on trying to assess dermal blood flow clinically. This technique can be inaccurate for determining that a scald burn definitely needs excision.

Q: Should scald burns be grafted early in a RLS?

A: Only if they are clearly deep burn wounds. Available evidence suggests that if doubt exists about clinical diagnosis of depth in a scald burn, then conservative management until about 10 to 12 days after injury is a logical approach because a significant proportion of scald burns of doubtful depth will heal well with conservative treatment. As the clinical appearance of the burn wound is unreliable for diagnosis of depth in scalds, the history should be carefully considered in such injuries. Deeper injuries occur in scalding with very hot liquids (especially containing fat or organic material); with prolonged exposure to the injuring agent; and in the young and old. In addition, unconsciousness at time of injury (e.g., with epilepsy or intoxication) or neuropathy are associated with much deeper scalds.

Q: When should ''early excision'' be performed for small- and moderate-sized burns?

A: For many burn services, if the burn is free of infection, early excision would be performed at the first available burn operating session.

Q: When should patients be mobilized after skin grafting for burns?

A: Grafts have generally taken well at 5 days, if they are going to take. Accordingly, unless the burns are in very high-shear or pressure-bearing areas, mobilization should be commenced after 5 days, so as to optimize functional outcome. To counteract secondary split skin-graft contracture, patients should also begin passive stretching and resting nocturnal splinting in an extended position as soon as the graft has taken.

Recommendation 4

In high-voltage electrical injuries, urgent surgery may be life-saving, and is necessary to allow the highest chance for limb salvage.

8.4. Considerations in formulating Recommendation 4

In very deep burns, especially high-voltage electrical conduction injuries, early fasciotomy for limb burns is indicated (see Escharotomy and Fasciotomy, page 18). Necrotic tissue should be excised. Breakdown of necrotic muscle, in particular, may cause life-threatening cardiac, renal and infective complications which can be prevented by judicious excision [192].

In some cases, amputation of a severely compromised extremity may be life-saving. Where sufficient surgical expertise is available, vascular and other soft-tissue reconstructions may be indicated. After initial burn wound excision, further debridement may be indicated to ensure adequacy of excision of necrotic tissue before reconstruction [193,194].

8.4.1. Balance of benefits and harms

When blood flow to extremities is compromised by compartment syndrome caused by high-voltage electrical injury, restoration of flow is absolutely necessary to maximize tissue salvage. However, the challenge is how to provide this necessary surgical treatment when trained personnel are not available. Such situations arise in LMIC but also in mass casualty incidents or situations in which medical transport is hampered by weather conditions. In such cases the decision has to be made whether or not inexperienced and untrained personnel should attempt fasciotomy or excision. When conditions allow for foresight and planning, consideration should be given to educating medical personnel on how to perform basic limb-saving procedures when they are functioning in RLS. The expansion of availability of telemedicine to provide education and real-time support from trained specialists may improve the quality of care in RLS in the near future.

8.4.2. Values and preferences

In some countries, the authority to perform procedures such as fasciotomies rests with appropriately credentialed medical professionals, such as surgeons. Although ensuring quality of care in normal conditions where resources are available, this becomes a barrier to immediate patient care when trained personnel are not present. In countries without such rigid restrictions on the performance of surgical procedures, this still becomes an ethical challenge—should untrained medical personnel be asked to perform procedures beyond their scope of practice if the only alternative is certain limb loss?

8.4.3. Costs

Fortunately, the direct cost of performing fasciotomies is quite low. The procedure can be performed with only a scalpel; if the injury is of full thickness, little or no anesthetic is required (See Escharotomy and Fasciotomy, page 18).

8.4.4. FAQs

Q: What are the risks of surgical intervention in high-voltage electrical conduction injury?

A: Risks include major reperfusion injury: rhabdomyolysis can cause renal failure from myoglobinuria and cardiac arrest from hyperkalemia. Severe systemic inflammatory response may also occur.

Exploration with fasciotomy, initially under tourniquet control, is the safest approach, especially if the patient has presented late after injury. Where possible, during surgery, clearly nonviable muscle should be debrided before reperfusion. If an excessive amount of nonviable muscle is allowed to reperfuse during surgery, renal failure and hyperkalemia may be overwhelming. In limbs with extensive necrosis, amputation prior to any potential reperfusion may be necessary to prevent fatal systemic complications. The anesthetist should be aware of the risk of reperfusion injury and its consequences.

Q: How soon should a patient with a high voltage electrical conduction injury have surgery?

A: High voltage injuries with muscle damage are surgical emergencies. After the patient has been fully assessed, resuscitated and stabilized, involved muscle compartments should be explored as soon as possible. Ischemic damage to muscles becomes irreversible after approximately 6 h.

Q: How often should burn wounds be re-explored before reconstruction after high-voltage injury?

A: There is no clear guideline regarding how many debridements are indicated for high-voltage injuries. Highly experienced surgeons may choose to carry out a single radical debridement before proceeding to immediate reconstruction. This is particularly indicated if the limb has to be revascularized. For surgeons less experienced in high-voltage injuries, it is prudent to undertake two or three debridements spaced over the first 5 days after injury before reconstructing the defect at about 5 days.

Q: Do all high-voltage electrical injuries involve muscle?

A: No, sometimes in electric arc injuries, the burn is predominantly a cutaneous flame or flash burn. In cases of arcing injury, the history, wound appearance, and absence of deep-sensor, motor or vascular signs will clarify the diagnosis. Creatinine kinase is a very useful investigation for diagnosing muscle damage.

Recommendation 5

Tangential excision is the standard method of burn wound excision. Fascial excision may be indicated in very deep burns and high-voltage electrical conduction injuries. In a resource-limited setting (RLS), conservative wound management, staged removal of separated slough, and delayed split skin grafting may be the most realistic approach, provided wound care is sufficient to prevent overt infection.

8.5. Considerations in formulating Recommendation 5

For most burn eschar excisions, tangential excision is the preferred method. It is quick and allows conservation of viable tissue (dermis and/or fat) deep to the burn. Typically the eschar is shaved tangentially and the dead skin and subcutaneous fat is removed. Most often this is carried out sequentially in relatively thin layers so as to avoid unnecessary excision of viable tissue. Using the tangential method in a sequential approach, viable dermis or subcutaneous fat is preserved, and aesthetic and functional outcome is enhanced [184].

The alternate technique of fascial excision commonly results in poorer aesthetic and functional outcomes because a significant amount of normal tissue is removed. This produces avoidable contour defects and deformity, and often, stiffness. However, fascial excision, especially with electrocautery, is usually associated with less bleeding than is tangential excision and fascial excision commonly produces reliable graft take by ensuring viability of the wound bed [197]. However, overall rates of graft take after tangential excision have been found to be similar to those after fascial excision [198]

Delayed debridement of slough to granulation requires lysis of the eschar by sloughing or lysis of the plane between the eschar and viable subcutaneous tissue. Commonly, this occurs by bacterial activity; hence, this approach is associated with a high risk of invasive infection.

Surgically, the traditional delayed debridement approach is a straightforward technique, requiring basic instruments such as a large curette, a metal ruler, or sterile steel wool to remove debris from a vascularized granulating surface. Typically this can be done with little blood loss. However, the more the surface-infected granulation tissue and debris can be removed, the cleaner the wound. It remains contentious how much tissue should be removed before grafting on granulating wounds, and some evidence supports that grafts take equally well on undebrided as on debrided granulating wounds [169]. Especially when escharotomies have been required, delayed debridement of burn wounds leaves the patient open to a high risk of invasive wound infection, and this accounts for the high mortality typically observed with a delayed approach.

8.5.1. *Balance of benefits and harms*

Possible disadvantages of the early tangential excision method are: the necessity for surgical judgment in determining burn depth so as to achieve adequate depth of excision [187]; increased propensity for bleeding [195]; and the possibility of progression of burn necrosis as the burn deepens with time [196]. Fascial excision is often indicated for burn excision in early large-area excisions, especially of burns on the trunk, and also for very deep burns on the limbs, where visualizing the muscles to assess for injury may be useful; it can also be useful for very deep burns of the neck.

8.5.2. *Values and preferences*

The depth of excision depends on the circumstances: in a major burn patient, during an early ''life-saving'' excision, it is sensible to excise a bit deeper than the surgeon feels is absolutely necessary to reach viable tissue. This ensures viability in all areas of the wound bed and protects against the burn wound becoming deeper with time (progression of the ''zone of stasis'' of the burn wound).

In a smaller burn, when excising to produce an optimal functional or aesthetic outcome, the goal is to preserve as much viable tissue as possible. If excising using a tourniquet or epinephrine tumescence, excision should be performed sequentially down to white shiny dermis and clear bright yellow fat, making sure that speckled coagulated dermis and brown/orange fat with coagulated veins are excised. With reperfusion of the wound bed, white dermis can become speckled later in the operation, so the surgeon should trust his/her initial excision. Excision down to bleeding tissue is a simple way of ensuring appropriate depth of tangential excision, but this is commonly associated with significant blood loss.

8.5.3. *Costs*

The differences in cost between tangential and fascial excision are minimal. Whereas fascial excision can be accomplished with a scalpel or electrocautery, tangential excision requires hand-held dermatomes. Yet these hand-held dermatomes are affordable and often present in most operating theaters. Because there is more blood loss with tangential excision, fascial excision typically saves the cost of blood transfusions (see discussion of Recommendation 6, below).

Recommendation 6

Burn wound excision and grafting can be undertaken without undue blood loss by using some or all of the following:

- Subcutaneous infiltration of burn wound and donor site, or topical application of epinephrine solutions, or both
- Tourniquets for limb surgery
- Fascial-type excision using electrocautery
- Other topical hemostatic agents such as thrombin and fibrinogen
- Prevention of hypothermia
- Compression dressings and limb elevation
- Staged burn excision

8.6. *Considerations in formulating Recommendation 6*

Low availability of blood for transfusion can inhibit the application of burn wound excision and grafting in burn units in RLS. Excessive transfusion after uncontrolled blood loss during surgery may cause a variety of significant complications. Increased transfusion requirement is associated with poorer outcomes [199]. Interventions that may be used to elevate the safety of burn excision surgery by reducing blood loss include the following [187]:

Subcutaneous vasoconstrictor infiltration

Epinephrine is probably the most readily available vasoconstrictor and has been used widely in concentrations in normal saline of from 1/200,000 to 1/1,000,000. Large volumes have been used safely, and benefit may accrue from infiltration deep to both the burn wound and the donor site. The technique can be extended using ''tumescent'' surgical techniques where the hydrostatic pressure of the fluid injected also reduces bleeding. Tumescence has the added advantage of aiding surgery in sites where the contour of deep anatomy may cause problems, such as in harvesting grafts from the abdomen or back, or tangentially excising on the chest. Subcutaneous epinephrine/saline infiltration makes a dramatic difference during excisional surgery on the face and neck, allowing improved visualization of the wound bed and providing more time for precise surgery.

Tourniquet control

Tourniquets for limb surgery make a dramatic difference in blood loss and also allow precise visualization for controlled surgery. The technique of sequential inflation and deflation/

elevation during excision, to check on viability of tissues and for hemostasis, allows large areas to be excised with minimal blood loss. A high thigh tourniquet may also allow some skin graft harvest with minimal intraoperative loss. An Esmarch bandage is an inexpensive alternative widely used in RLS but does not allow the facility for controlled inflation/deflation which is particularly useful for confirming viability and bleeding. In addition, inability to control pressure may result in nerve injury. Accordingly, Esmarch tourniquet bandaging may be safest when used only for relatively small excisions.

Topical hemostatic agents

Topical epinephrine/saline-soaked dressings applied to excised wounds or donor sites have been shown to be beneficial as part of a system of blood-loss control. Concentrations of from 1/33,333 to 1/100,000 are most commonly used. Application under compression is likely to achieve an optimal benefit. Thrombin and fibrinogen are effective topical hemostatic agents which are less likely to be available in RLS.

Prevention of hypothermia

Core temperature below 36 °C may be associated with impaired clotting and increased bleeding. Accordingly, a high ambient temperature, warming of administered fluids, direct patient warming, and avoidance of unnecessary patient-skin exposure are crucial aspects of care during burn surgery. In addition to causing coagulopathy, intraoperative hypothermia may cause impairments to metabolism, immune status, cardiac performance and neurologic function [186].

Compression dressings and limb elevation

Judicious use of compression bandaging and elevation of the operative site can dramatically reduce intra- and postoperative bleeding from excised wounds. This practice is widely used after burn surgery on the limbs. Elevation should also be used in careful positioning of the patient after surgery of the head and neck. If compression dressings are used, undue postoperative pain or paresthesia may be signs that bandages need to be loosened. It is important to monitor postoperative patients for these signs.

Staged excision

Massive burn excisions may cause coagulopathy and massive fluid shifts which can lead to uncontrolled bleeding and irreversibly destructive complications.

It is tempting to excise as much full thickness burn as possible at the first episode of surgery, with the aim of reducing systemic inflammatory response and hypermetabolism, as this has been shown to produce the highest rates of survival per %TBSA. However, for many patients, in many burn care services, the safest course is to carry out repeated, more modest excisions spaced a few days apart until all of the full thickness burn is excised (*staged excision*, also sometimes known as *sequential excision*, although the latter term is more commonly used to describe a technical approach of gradually excising dead tissue during tangential excision).

8.6.1. *Balance of benefits and harms*

The main concern with subcutaneous vasoconstrictor infusion techniques is that experienced surgical judgment is required to determine depth of excision, as telltale pinpoint bleeding is often not present, and bruising from the injections may mimic the appearance of coagulated vessels in the dermis and subcutaneous fat. In young children, it is important to take into account the volume of saline infused. Similarly, experienced surgical judgment is required to determine viability of tissues under tourniquet excision. With the limb exsanguinated, fixed dermal staining or orange/brown discoloration of the fat indicates nonviable tissues.

8.6.2. *Values and preferences*

The staged excision technique reduces the stress of surgical episodes while still allowing excision of all deep burn at a relatively early stage in the patient's management. As such, this is the standard of care in many units throughout the world. Staged excision is strongly indicated in patients with preexisting morbidity (e.g., ill or elderly) or patients whose systemic condition is unstable (for example, after inhalation injury).

Regarding the use of tourniquets in African burn units, it is crucial to be aware that tourniquets can cause devastating problems in people with sickle-cell conditions. Well-functioning pneumatic tourniquets are a great advantage for burn excisions but may not be widely available in RLS. Esmarch bandage is a good substitute, but excessive duration of use of Esmarch can cause complications with tissue damage, especially nerve palsies. During excision under tourniquet, it is important to develop the ability to identify when viable dermis or fat is reached (white shiny dermis without coagulated vessels and clear yellow fat). If the wound bed is visualized again later in the operation, it will often have an appearance of a deeper burn, with speckling, because of reperfusion of the wound bed. If this issue is not duly appreciated, unnecessarily deeper excision may result [173].

8.6.3. *Costs*

The costs of supplies and equipment for these blood-saving techniques are appreciable but are easily offset directly by the reduction in the number of blood transfusions, and indirectly by improved patient outcomes.

8.6.4. *FAQs*

Q: Which epinephrine/adrenaline solutions should be used for injection and infiltration? How should they be mixed?

A: For infiltration, a good all-purpose solution is 2 mL of 1 mg/mL of epinephrine in 1000 mL of normal saline, producing a concentration of 1 in 500,000. Stronger concentrations may be used for facial burn excision. The fluid should be warm. For topical application, 30 mL of 1 mg/mL of epinephrine in 1000 mL of normal saline produces a solution of 1 in 33,000, which is a potent topical hemostatic agent. The solutions should be carefully marked to avoid accidental injection of the potent topical application solution.

Recommendation 7

After excision or debridement of the deep burn wound, it is essential that the wound is covered with autograft skin or an appropriate skin substitute.

8.7. *Considerations in formulating Recommendation 7*

Removal of the burn eschar creates a potential open portal for invasive infection. In addition, massive fluid, electrolyte and

protein loss may occur. The extent of excision should be planned to allow the greatest advantage of available autograft or allograft skin, so that the wound may be closed immediately after burn excision. Adequate wound closure also promotes optimal hemostasis after excision.

Planning of harvest of autograft should take into account the systemic insult to the patient (potentially turning a major burn into an even larger one), and subsequent requirement for quality autograft skin for important sites such as hands and face.

8.7.1. *Balance of benefits and harms*

A wound too large to be safely repaired with autograft should be repaired with allograft or skin substitute [179,180]. In a RLS this may dictate a plan for staged burn excision or conservative treatment [181]. Failure to achieve adequate wound coverage after excision commonly results in invasive infection, or at best, desiccation of the exposed wound surface. It is almost certainly better not to excise burn eschar than to excise it and be unable to achieve coverage of the excised wound.

8.7.2. *Values and preferences*

Five substitute alternatives can be used to replace autograft following excision or debridement of deep burn wounds. These alternatives are described below.

1. *Human allograft skin*
   Cryopreserved allograft is widely used and can provide good quality temporary skin cover for excised wounds for several weeks, until rejection occurs. Cryopreservation allows full donor-virus testing to be carried out so as to avoid risk of transmission of illness.
   Fresh allograft is the most effective skin replacement, and takes for many weeks, but fresh cadaveric allograft is seldom readily available. Fresh donor-related allograft (typically from a parent) may be suitable for small children, but is not widely used. Glycerol-preserved or lyophilized skin is nonviable, and functions as a very good biologic dressing rather than a vascularized graft. It can be very effective as a short-term cover (up to approximately 2 weeks) for excised wounds.
2. *Dermal regeneration matrices (or templates)*
   Following the successful introduction of a bovine collagen–based dermal regeneration template, a number of dermal regeneration products have been used. These biosynthetic products have been derived from bovine collagen, human allograft dermis and porcine dermis, and also from synthetic substances. These acellular products are commonly based on collagen, and produce a matrix on which a ''neodermis'' may regenerate.
   Broadly, these acellular products can be divided into those for either two- or one-stage use. The two-stage products are most suitable for acute major burns, as they provide temporary wound closure, prior to secondary autografting later with thin autograft or cultured cells (for instance: with Integra®, short-term wound closure is achieved with a surface silicone layer, which is removed prior to autografting at approximately 3 weeks, when ideally the patient is more stable). The one-stage use products offer the advantage of enhanced dermal reconstruction with very thin autograft harvest, but if used immediately after burn injury, they require a donor site of the full extent of the wound.
   Of techniques evolved to date for major burn injuries, the dermal regeneration matrices are probably the closest to producing a widely available, reliable ''synthetic skin. However, they do require full coverage with autograft epithelium. Disadvantages of the dermal regeneration matrices include a higher risk of problems with infection than with autograft or allograft, and relatively high cost which precludes anything but the most occasional use in a RLS.
3. *Xenograft-derived temporary wound coverage*
   The most common source of xenograft material for use in burns has been porcine-derived materials. These have included untreated pigskin; cryopreserved pigskin; lyophilized porcine dermis; and popular biosynthetic products composed of porcine collagen with nylon and silicone. Considerable evidence supports the value of many of these materials when used as dressings in treatment of partial thickness wounds. For excised deep burn wounds, these xenograft products produce only short-term reliable wound cover (a few days). This can be useful in getting a patient safely through a major burn excision, before later application of definitive wound cover; but if used for more prolonged periods on excised wounds, the risks of invasive infection are higher.
4. *Amniotic membrane*
   Amniotic membrane is potentially universally available as good short-term coverage for excised wounds, and as a biologic dressing. In some RLS, its availability has been restricted by the cost of virus testing and by resultant practical barriers to its use. Amniotic membrane can be stored as cryopreserved, irradiated, or glycerol-preserved and in many parts of the world this has proved a useful technique for short-term coverage of excised wounds.
5. *Cell-based therapies*
   Cultured epithelial cells have been widely used in burn treatment, both as autograft and allograft. Autograft takes time to grow, so it is not available as an immediate skin substitute for early major burn excision.
   Although cultured epithelium has gained acceptance for many indications in burn-wound management, problems with failure of adhesion of cultured epithelium to full thickness wound beds and poor durability of cover mean that cultured cells have not achieved a consistently effective role as the sole skin replacement for full thickness wounds. Cultured epithelium serves best where a native or regenerated dermis is present in the wound bed.
   Similarly, autologous epithelial cells in suspension, or stem cells of a variety of origins, have been shown to have significant potential for enhanced healing of a variety of burn wounds: partial thickness wounds, wounds covered with meshed skin grafts, or wounds where dermis (native or regenerated) is present. These techniques have huge potential for skin replacement therapies in future.

8.7.3. Costs

In RLS, allograft skin, amniotic membrane and porcine xenograft have all been used. Commonly, cultural factors relating to donation will influence possible use of allograft in many countries. In addition, viral testing is essential for human skin and amniotic membrane. Notwithstanding these issues, banking of these skin substitutes can be of relatively modest expense, and it may be realistic for a low-resource service to aim to institute a tissue-banking service.

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9. Nonsurgical management of burn scars

Part I: Scar Management: Prophylactic (Preventive) Setting

Recommendation 1

Superficial burns (wounds that heal in <2 weeks) require topical emollients/humectants, sun protection, and massage after healing.

9.1. *Considerations in formulating Recommendation 1*

Patients with *deep dermal burns* achieve healing by means of spontaneous re-epithelization of burn wounds, which is generally prolonged (>3 weeks), and thus are at great risk of developing excessive scarring. The depth of the burn wound determines the ensuing severity of the inflammatory and proliferative phases of the wound healing. Some evidence suggests that the fibroblasts from the upper papillary dermis show limited activity in laying down extracellular matrix [200], and this limited activity, along with the robust migration of keratinocytes from the viable epithelial appendages, in *superficial burns*, leaves no opportunity for hypertrophic scarring.

If treated nonsurgically, the whitish, waxy eschar seen in deep dermal burns prolongs the wound healing and some wounds are even converted to full thickness wounds because of infection and desiccation. Wang et al. have shown in their studies that deep dermal fibroblasts resemble fibroblasts of hypertrophic scars (HScs), suggesting that these fibroblasts may be central to HSc formation [201]. Thus, even if the inflammatory process of deep dermal wounds is controlled by meticulous wound care and debridement, such wounds are naturally predisposed to a prolonged and excessive proliferative phase.

In skin grafted wounds, especially in people with darker skin, there is the potential for the wound edges to become hypertrophic. Therefore, patients at risk for hypertrophic scarring from such burn areas should be identified as soon as thickening of the skin becomes apparent, to receive measures to prevent the development of hypertrophic scarring. Risk of scarring, based on risk profile, should serve as a starting point, and then confirmed or acted upon at 4–6 weeks post burn; that is, before thickening or negative symptoms in the scar become established, when scars will be less treatable through conservative means.

Suetake et al. have shown that after wound healing, water still evaporates more rapidly through scar tissue and may take over a year to recover to pre-wound levels [202]. Prevention of drying also helps in combating pruritus that may lead to reinjury of the newly healed areas.

Shin and Bordeaux conducted a meta-analysis of the literature to evaluate the efficacy of massage therapy. Included were data from ten different publications regarding 144 patients. The investigators concluded that although scar massage is anecdotally effective, supportive evidence is weak and outcome measures are not standardized [203]. Yet, even though no strong clinical evidence shows massage leads to faster maturation of the healed burn wounds, massage therapy is psychologically beneficial to patients. It fosters a sense of well-being and promotes greater mobility in patients recovering from burn wound injury. Massage also helps control distressing symptoms of burn scar pruritus [204]. In addition, it releases tight muscles and the functional contractures which may develop into scar-related (skin) contractures. The newly regenerated epidermis gradually becomes populated with melanocytes from within the hair follicles, and with the progress of time, the pigmentation of the healed skin approaches that of uninvolved skin. The final match of pigmentation of healed skin to the normal skin is unpredictable. Experimental as well as clinical evidence suggests that ultraviolet exposure to the recently healed scars causes increased melanocyte response and hyperpigmentation [205]. It is evident from cumulative clinical evidence that all such recently healed burn wounds require sun protection until the maturation phase is complete (duration not less than one year post-burn) by means of barrier clothing, sunscreens, and lifestyle and behavioral modifications.

9.1.1. *Balance of benefits and harms*

Until the pre-existing, surviving epithelial appendages (sweat glands, sebaceous glands) resume their normal function, keeping the healed skin moist with the use of emollient/humectant creams or lotions is soothing and protective. There has been no report of any harm ensuing from emollients/humectants, sun protection creams, or massage.

9.1.2. *Values and preferences*

Strategies to keep the skin moist may include products such as creams, aloe vera, petroleum jelly, vegetable oils and silicone therapy, some of which may be too expensive for patients to purchase. Petroleum jelly (Vaseline™) and vegetable oils, both emollients, are inexpensive, widely available, and usually applied with massage. Mustoe has reviewed the evolution of silicone based therapies for scar management over the years [206]. Silicone therapy in the form of spray, gel or gel-sheets reduces the trans-epidermal loss of moisture from the applied area and helps in maturation of the burn scar. However, for superficial burns it should be sufficient to apply simple emollients rather than silicone gels/sprays.

9.1.3. *Costs*

Coconut oil has been widely used as an emollient on burn scars because it is relatively inexpensive and easily available in many resource-limited settings (RLS). Sun protection creams may be unaffordable or they may not be available in RLS so it is better to restrict exposing such burn areas to direct sunlight by use of clothing, umbrellas, and caps, which can help in placing a barrier to ultraviolet light exposure.

9.1.4. FAQs

Q: What is the difference between emollients and humectants?

A: Although the distinction between **emollient** and **humectant** may be confusing, they differ by mode of action. Many humectants also have emollient properties, while not all emollients are humectants. Bottom line: they both keep the skin well hydrated either by reducing trans-epidermal water loss or by bringing moisture to the skin surface; therefore moisturizers, humectants and/or emollients can be used interchangeably in burn care. The best moisturizers combine emollients and humectants.

Emollient: From a Latin word with the same spelling, meaning ''to make soft.'' Moisturizers or emollients are complex mixtures of chemical agents specially *designed to make the external layers of the skin softer and more pliable*; they increase the skin's hydration by reducing evaporation. Most people use the terms ''moisturizer'' and ''emollient'' interchangeably, though typically an emollient describes a particular ingredient contained within a finished moisturizer. Emollients are used to soften and smooth the scales of the skin, thus helping to reduce rough, flaky skin. They are also occlusive agents: substances that provide a layer of protection that helps prevent moisture (water) loss from the skin. Examples of where emollients can be found are in silicone (dimethicone, cyclomethicone), vegetable oils (grape seed, sesame seed, jojoba, etc.), butters (cocoa butter, shea butter), alcohols (stearyl alcohol, cetyl alcohol), and petroleum derivatives (petroleum jelly, mineral oil).

Humectant: A substance, especially a skin lotion or a food additive, *used to reduce the loss of moisture*. A humectant is a hygroscopic substance used to keep things moist; it is the opposite of a desiccant. A humectant's molecules contain several hydrophilic groups, most often hydroxyl groups. A humectant attracts and retains the moisture from the air nearby via absorption, drawing the water vapor into and/or beneath the organism/object's surface and actually bonding with water molecules to increase the water content in the skin itself. Humectants can draw water from a humid environment, and they enhance water absorption from the outer layer of skin. Glycerin is one of the more typical and effective water binding agents. Other humectants include sugars (glucose, fructose, sucrose, honey), proteins, amino acids, elastin, and collagen.

Recommendation 2

Deep dermal burns (wounds that heal in >3 weeks) require aggressive and monitored scar-prevention therapies augmented with appropriate pain relief and combined with early positioning regimens and physiotherapy for joint mobilization to prevent hypertrophic scarring and joint contractures. These measures are required in addition to topical emollients, sun protection and massage after healing.

9.2. Considerations in formulating Recommendation 2

Scar prevention therapies that mitigate ongoing inflammation will have a beneficial effect on the scar formation in deep dermal burns. One of the established methods of reducing the inflammatory process is to excise the deep dermal wound early and perform skin grafting. A myriad of published and clinical evidence supports this measure of dealing with such wounds.

Pressure therapy (PT) with or without silicone therapy is used commonly as a first-line modality to prevent hypertrophic scarring in treatment of burn patients. Use of PT leads to reduction in collagen synthesis by various proposed mechanisms such as reducing the vascular and nutrient perfusion in the scar. PT is also believed to reduce the inflammatory milieu within the immature, erythematous, pruritic burn scar [207].

However, a meta-analysis conducted by Anzurat et al. concluded that until further evidence becomes available, clinicians should consider the potential costs and complications of pressure garment therapy (PGT) in the prevention of abnormal scarring after burn injury [208]. In their opinion PGT may decrease scar height but fails to alter global scar scores significantly. Nevertheless, for post-burn scars, most burn practitioners still recommend this modality for scar modulation as it is non-invasive and easily available, and has been used in practice over many decades. Moreover, a ''within-wound'' comparative study, conducted subsequently to that meta-analysis, concluded that PGT was effective in moderate to severe scarring [209]. PT is so well ingrained in scar management that decisions to conduct randomized controlled trials (RCTs) to study its efficacy at this stage may even be considered unethical [207]. Problems looming with PT also pertain to lack of a clear definition for hypertrophic scarring, and an inability to ensure requisite pressure in all body areas and to enforce strict compliance by the patient.

A 2006 Cochrane meta-analysis reported that silicone gel sheeting reduces the incidence of hypertrophic scarring in high-risk individuals compared with no treatment (response rate: 0.46; 95% confidence interval, CI: 0.21–0.98) [210]. However, a more recent Cochrane meta-analysis including 20 clinical trials found that although silicone gel sheeting reduced scar thickness and improved scar color with statistical significance, the analyzed studies were of poor quality and highly susceptible to bias, with weak evidence of efficacy in preventing abnormal scarring in high-risk patients [211]. The recommendation for its use still continues to be strong.

Li-Tsang et al. demonstrated that silicone sheeting can be combined with PT to produce greater improvements in post-traumatic HScs than is produced by either therapy alone [212]. The two treatments have complementary modes of action, with the silicone therapy acting on the erythema and pliability of the scar, and the PT preventing scar thickening. However, a later RCT conducted by Steinstraeseer et al. with intra-individual comparison does not show any increased benefit of using PT combined with silicone gel sheeting compared with the use of PT alone in a preventive setting [213].

Because of contractile forces acting in such wounds there is a high possibility of developing contractures if the wounds straddle flexion surfaces of the joints, and either consistent range of motion exercises or appropriate splinting or both is essential to prevent deformities. (This concept is detailed further in the section on Positioning of the Burn Patient, page 57.) Over the years clinical practice has evolved to the extent

that at this stage it is unnecessary to test these observations about positioning by means of additional RCTs.

9.2.1. *Balance of benefits and harms*

In a prophylactic setting, there is currently much value in persisting with combined PT and silicone therapy to prevent exuberant scarring, which can be a cause of severe pruritus as well. In a prophylactic setting, PT by means of limiting blood supply to the scar may be effective in restricting scar erythema. For extensive hypertrophic scarring there is largely no other valid modality of treatment.

9.2.2. *Values and preferences*

Conventionally, pressure garments are prescribed as soon as healing is complete. The elastic pressure garments must deliver 20–32 mmHg pressure on the applied area [214]. An International Advisory Panel on Scar Management (2002) recommended the use of silicone based therapy beginning 2 weeks after wound healing for prevention of excessive scarring [215]. It is recommended that gel sheets be worn for 12–24 h and any additional gel used should be applied twice daily. Duration of treatment is recommended for 20–23 h per day (removed only for hygiene and moisturization) for at least 2 months and as many as 9 months. Updated International Clinical Recommendations on Scar Management, published in 2014, continue to recommend the use of silicone based therapy combined with pressure garments in the prevention of excessive scarring [216].

9.2.3. *Costs*

Contrasting the high costs for PT in the developed countries, the costs can be surprisingly very low in RLS if the product is manufactured locally or procured from a similar country with manufacturing facilities. However, some pressure garments such as Tubigrips® are less reliable with pressure gradients. Use of Micropore™ tape can also serve to enhance scar hydration if silicone products are unaffordable [217].

Part II: Scar Management: Treatment of Established Hypertrophic Burn Scars

Recommendation 3

a. All extensive burn hypertrophic scars should receive pressure therapy with silicone therapy as the first line of treatment.
b. Restraint should be applied in opting for the surgical modality before scar maturation unless the scar is functionally limiting because of a developing contracture.

9.3. *Considerations in formulating Recommendation 3*

In the natural, untreated course of post-burn hypertrophic scars, most show reduction in height, pain, pruritus and redness over a period of time. With time, HScs become flatter and more pliable. The time lapse before post-burn HScs mature is often underestimated but actually takes considerably longer, perhaps up to 2 years [218]. Any operative insult to an erythematous scar sets back the clock and may lead to an undesirable result. However, exceptions to this general rule are in cases where patients suffer a major functional loss that must be treated surgically. These situations must be addressed at the earliest juncture as these patients are not likely to respond to range of motion exercises, positioning, and splinting. These conditions include ectropion of eyelids and debilitating contractures of the neck, hand, cubital fossa, and popliteal and perineal regions.

Younger lesions respond better to nonsurgical modalities. A critical evaluation of silicone based therapies has been alluded to in Recommendation 2 of this chapter [219]. Silicone products reduce the trans-epidermal loss of moisture and increase the local temperature. Although a recent Cochrane review found a risk of bias in the studies evaluating the efficacy of silicone therapy, the results showed with statistical significance that silicone gel sheeting reduced scar thickness and improved scar color [211].

Pressure therapy delivering compression to HScs continues to be widely prescribed to improve scar characteristics, especially scar height. Even though the meta-analysis by Anzarut et al. did not find strong evidence for improvement of scars with PGT, except a statistically significant reduction in the scar height, an in-depth study of this article shows that the participating studies had too extensively varied inclusion criteria and protocols to be really comparable [208]. Again, as mentioned above, the use of both silicone gel sheeting and PT together theoretically maximizes the chances of resolution of hypertrophic scarring [212].

9.3.1. *Balance of benefits and harms, values and preferences, and costs*

These issues were described above for Recommendation 2 of this chapter. Undoubtedly, both the modalities demand high levels of motivation and compliance on the part of patients. What is required of health care practitioners is attention to appropriate pain management as well as education of the patient and family about range of motion exercises, positioning, splinting, and PT as they relate to restoring optimal function.

Recommendation 4

The role of intralesional therapies is limited to small and discrete scar hypertrophy.

9.4. *Considerations in formulating Recommendation 4*

Many agents are useful when administered intralesionally. Some of these include steroids (triamcinoloneacetonide/TAC), anti-tumor agents (bleomycin, 5-fluorouracil [5-FU]), calcium channel blockers (verapamil), and cryotherapy via microneedling.

Injection TAC has enjoyed a long history of use and is the current gold standard against which newer intralesional modalities are tested. TAC reliably improves the scar characteristics when injected at the doses of 10–40 mg/mL intralesionally every 3 to 4 weeks, over four to six treatment sessions[220]. Corticosteroids ameliorate the inflammatory milieu in the scar and lead to a reduction in the levels of

proteinase inhibitors (α-2-macroglobin and α-1-antitrypsin) which increase collagenase levels leading to collagen degradation [221].

In a RCT, Ahuja and Chatterjee found injection verapamil to be as effective as injection triamcinolone even if the onset of action is slower with the latter [220].

A wide body of data support the use of intralesional 5-FU in the treatment of HScs and keloids. Intralesional 5-FU inhibits fibroblast proliferation and is found to be very effective in erythematous HScs. This agent is reliable, predictable, and has found acceptance by the Updated International Clinical Recommendations on Scar Management (2014) [216]. A newer agent such as bleomycin, by decreasing collagen synthesis, has also shown efficacy in the treatment of resistant lesions, especially older scars and keloids [222].

Similarly, there are several studies reporting efficacy of cryotherapy. One large study on 166 lesions reported a response of 79.5% with a volume reduction >80% after a median of three treatments (range: 1–9) [223].

9.4.1. *Balance of benefits and harms*

The clinical management of scarring is complicated by a lack of precise characterization of each scar category, interchangeable use of the terms 'hypertrophic scars' and 'keloids,' a lack of appreciation of keloid diathesis as an independent entity, and the availability of few therapeutic interventions that are supported by well-designed prospective studies involving adequate control groups [224]. However, the abovementioned intralesional drugs have been selected here as their use is well documented. The drug dosage, end point of injection, time intervals, endpoint of treatment, etc., are also at such variance that it is difficult to standardize an approach. Only recently Ahuja and associates have attempted to rationalize conclusions based on these issues for the use of injection TAC and injection verapamil [220].

Extravasation of injection TAC into peri-scar tissues can lead to hypopigmentation and skin atrophy and any extravasation of anti-tumor agents can lead to skin atrophy or sloughing. In addition, injection bleomycin causes hyperpigmentation in darker skin [222]. The main adverse effects reported with cryotherapy are atrophic depressed scars and residual hypopigmentation [223].

9.4.2. *Values and preferences*

The above modalities have not been studied for extensively involved areas of skin because the amount of drugs used would exceed their therapeutic dosage. It is believed that all young hypertrophic and keloid scarring does respond to injection TAC or injection verapamil, and antimitotic agents should be reserved for scarring in resistant lesions and for keloid diathesis [224]. However, for older lesions, injection TAC combined with cryotherapy markedly improves response rates and is the modality used currently in widespread practice [225]. Numerous reports in the literature attest to the efficacy of intralesional agents used in various combinations when the lesions do not respond to monotherapy. In one RCT the overall efficacy of a combination of triamcinolone with 5-FU was comparable to that of triamcinolone alone, although the combination produced better results [226].

9.4.3. *Costs*

The choice of scar management technique needs to be individualized based on the characteristics explained above and on treatment costs. Verapamil is the least expensive intralesional injection available. Pressure garments and silicone materials are available in a wide range of cost.

9.4.4. *FAQs*

Q. What is the role of onion extracts in the management of scars?

A. Onion extract (extractumcepae) is an ingredient found in many over-the-counter scar treatment formulations (for example, Mederma® and Contractubex®). These products are popular with laymen and have brisk commercial sales. No reliable evidence supports their use at present, and most studies investigate their use in combination with triamcinolone and/or silicone making it difficult to recommend them as monotherapy.

Q. What is the role of lasers in the management of postburn scars?

A.585/595-nm short-pulsed PDL (pulsed dye laser) can cause selective destruction of microvasculature and can extinguish the hypervascular response. Therefore, this technique can be used to treat young, erythematous and pruritic scars to hasten their maturation; but there is still a lack of strong and sufficient evidence to put forward a recommendation [227].

Most promising results for improving texture and pliability of thick scar tissue have been shown from studies using nonablative fractional lasers (NAFL) [228]. Jin et al. conducted a meta-analysis to evaluate the efficacy of laser based treatments for excessive scarring by including 28 well-designed clinical trials with 919 patients [229]. Although the studies confirmed the safety and efficacy of laser therapy for the treatment of HScs, they found a low level of evidence in the treatment of keloids.

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10. Infection prevention and control

Recommendation 1

A clean hospital environment should be maintained.

10.1. *Considerations in formulating Recommendation 1*

A clean hospital environment and high standards of cleanliness help to prevent the spread of health care associated pathogens. Infections in hospitals spread via three main environmental routes: surface contact, air, and water. Contaminated surfaces, therefore, play a role in the transmission of such pathogens [230,231]. In a prospective study involving 23 hospitals, opportunities were noted in all to improve cleaning of objects in the patient's immediate environment [232].

Specific microorganisms, including *Acinetobacter baumannii*, have a propensity to inhabit environments where dust exists and can be difficult to eradicate [233,234]. Routine environmental cleaning measures have been shown to reduce both vancomycin-resistant enterococcus (VRE) surface contamination and the acquisition of these multi-drug resistant organisms (MDRO) by patients in a medical intensive care unit (ICU) setting [235]. Prior room contamination, whether measured by environmental cultures or simply by prior occupancy by VRE-colonized patients, has been shown to be highly predictive of subsequent VRE acquisition by patients [236]. Identical strains of MDRO have been identified both in patients in a burn unit and in their immediate environment [237].

Microbial monitoring of the environment can be useful to assess levels of hygiene and the efficiency of clinical cleaning [238,239], although there is a lack of agreement as to what is an acceptable level of surface contamination [240]. Hospital surfaces, sinks and drains can in fact show a higher level of contamination with MDRO than the hands of workers (which may be subject to more regular cleansing) [241,242]. A study analyzing 168 environmental samples from a burn ICU identified the sink as the most common site for the isolation of organisms, and in particular, *Pseudomonas aeruginosa* [243]. Little evidence links the use of routine environmental surveillance with a reduction in clinical infections, although

such monitoring can be useful as part of an outbreak investigation.

Regular cleaning is important to ensure a clean and dust-free hospital and to prevent contamination of the environment by pathogens, in particular MDRO, and their transmission between patients [244]. Horizontal surfaces and toilet areas should be cleaned daily. Shared bathing areas in burn units are a source of cross contamination and should be cleaned and disinfected after each patient's use [245,246]. Isolation rooms and other areas frequented by patients with known infections should be cleaned at least daily, using a neutral detergent or disinfectant solution [247]. However, a systematic review conducted in 2004 failed to confirm a link between disinfection and the prevention of health care–associated infections (HCAI) [248]. Mechanical removal of visible dirt and biologic materials is thus the most important step in the cleaning process and the use of hot water (80 °C) and detergent can also be effective [249]. All equipment should be regularly cleaned, and, if a requirement calls for it to be shared between patients, it should be decontaminated with appropriate disinfectant before and after each patient's use.

Any areas showing contamination with blood or other body fluids should be cleaned immediately. This can be undertaken by nursing staff if the cleaning or housekeeping personnel are not available at that time. In these circumstances, a 'rapid response cleaning team,' staffed separately from the ward-based cleaning personnel, can be effective in responding to such hygiene needs in different parts of the hospital. This may not always be an option in resource-limited settings (RLS).

The topic of the design of the structural hospital environment is beyond the scope of this guideline, although this design influences the incidence of infection transmission. Good air quality is important in preventing airborne infections [250]. Appropriate ventilation, air filtration, and sterilization by ultraviolet lamps can reduce the levels of airborne pathogens. Laminar airflow patient isolation units have been shown to be effective in burn centers [251]. Engineering controls, such as ventilation systems that utilize pressure differentials can be effective in reducing airborne transmission of infection [252]. Interventions such as high-efficiency particulate air (HEPA) filters have been associated with lower concentrations of microbes in the air in a burn unit in Thailand [253] and lower nosocomial infection rates [254]. The use of a High-Intensity Narrow-Spectrum light Environmental Decontamination System (HINS-light EDS) has been shown to reduce bacterial contamination in a burn unit over and above that achieved by standard cleaning alone [255].

However no consensus has been reached on the most effective design interventions to prevent transmission of infections between patients with serious burns.

Single-bed isolation rooms, when available, are superior to multi-bed rooms in the prevention of airborne transmission of pathogens [250] and have been associated with decreased gram-negative bacteremia and decreased mortality in burn patients, when compared with an open-ward setting [256].

Guidelines for the prevention of hospital acquired infections published in the Indian Journal of Critical Care Medicine recommend that patients with larger burn injuries be isolated in private rooms or other enclosed bed spaces to ensure physical separation from other patients on the unit [257].

10.1.1. *Balance of benefits and harms*

Health care–associated infection affects millions of people globally and in developing countries can complicate the management of over 25% of patients admitted in acute care hospitals [258]. Patients with burns are susceptible to acquiring infections, and it may well be that the numbers are even higher in this patient group. Therefore, sustained efforts to maintain infection control and attention to prevention of transmission of pathogenic microorganisms could provide real benefits to these patients.

10.1.2. *Values and preferences*

Not all cleaning staff may have a full understanding as to the importance and relevance of their role. There is evidence that this can be addressed through education and supervision.

In a study conducted in a teaching hospital in Brazil, hospital housekeeping staff accomplished 25.37% of clean surfaces before and 80% after an educational intervention ($p = 0.01$). This finding demonstrated the potential impact of education coupled with monitoring [259].

Education and information should also be extended to patients, their families and visitors. All have a role in maintaining a clean hospital environment. A study undertaken in Bangladesh showed that in this developing country, patients' perceptions of the quality of a service improves their satisfaction with that service [260]. The cleanliness of the environment is one aspect of the quality of a service that is highly visible to all users.

10.1.3. *Costs*

The main cost associated with maintaining a high standard of environmental cleanliness is the employment of those who undertake the cleaning. These individuals are among the lower paid workers in acute health care in many countries and cost should not be a major barrier to implementing this recommendation.

Further costs may be incurred by microbiologic monitoring of the environment to ensure the effectiveness of the cleaning [261]. Supervision and education can represent an additional cost; this should be more than balanced by the potential reduction in HCAI and associated costs of patient complications, prolonged hospital stay, and poor outcomes.

Environmental design modifications as outlined above can be introduced at costs ranging from fairly modest up to major expenditure, including increased energy costs, for example for HEPA filtration. However, none of these modifications are likely to benefit patient outcomes if thorough cleaning to a high standard is not already in place.

Recommendation 2

Hand hygiene guidelines should be taught, implemented and monitored.

10.2. *Considerations in formulating Recommendation 2*

Hand hygiene is widely acknowledged to be the single most effective measure to prevent transmission of infection both from patient to patient directly and from the environment to

patients. Optimal hand hygiene is considered to be the basis of HCAI prevention [262,263]. The importance of this topic in the global challenge of improving patient safety is addressed in the World Health Organization Publication; WHO Guidelines on Hand Hygiene in Health Care (2009). The document can be accessed at http://whqlibdoc.who.int/publications/2009/9789241597906_eng.pdf [264] and is an excellent resource of evidence and recommendations.

Designing and conducting ethical randomized controlled trials in the field of hand hygiene is challenging, so guidelines are based on observational studies, studies with volunteers and expert opinion [265].

Although all health care services that care for burn patients should maintain written guidelines for hand hygiene, the other important aspect of this recommendation is the need for promotion of good practice and monitoring of compliance. A study undertaken in a low-income setting in Nigeria demonstrated improvements achieved in hand hygiene by interventions comprised of a combination of education, introduction of hand rub, and visible reminders for staff [266]. A multi-modal strategy is therefore the most likely to be successful in bringing about behavioral change that is sustained beyond the time of the initial intervention [267]. This practice is supported by a single-hospital study examining hand hygiene compliance before and after a multi-modal intervention, with the assessment repeated one year later. Compliance improved from 54.3% to 75.8% ($p = 0.005$) and this was sustained at one year follow up [268]. However, a Cochrane review undertaken in 2010 found there was insufficient evidence to be certain which strategies or interventions are most successful at improving hand hygiene compliance. Success in improving hand hygiene was inconsistent between the different studies included in the review [269].

Worldwide, family members partake in caring for hospitalized burn patients and in some countries a high proportion of the care itself is provided by relatives. Thus it is important that information and education is directed not only to staff but also to non-health care professionals involved with patient care. A study of family caregivers in a tertiary hospital in Bangladesh observed 2065 episodes of caregiving, 75% of which involved close patient contact. Hand washing with soap was observed on only 4 occasions [270]. Hospital staff, patients, families and visitors should be directly included in initiatives to improve hand hygiene [271,272] both by education and efforts to challenge poor practices.

Evidence has shown the benefits of using alcohol-based hand rub (ABHR) for routine hand hygiene [273]. In addition, ABHR has been shown to be significantly superior to hand washing with soap and water in a community setting in Tanzania [274]. A systematic review of publications between 1992 and 2002 revealed that ABHRs remove organisms more effectively and require less time than hand washing with soap or other antiseptic agents and water [275]. The usage of ABHR can also act as a proxy indicator of hand hygiene practice in a clinical area, saving the need for self- reporting (known to be inaccurate) or time-consuming direct observation [275]. Consumption of soap, ABHR and paper towels have all been associated with a reduction in HCAI [276,277]. Conversely, a reduction in the availability of hand-washing facilities has been associated with higher rates of HCAI [278].

The use of personal protective equipment (PPE) is an essential element in the prevention of HCAI. All health care institutions managing patients with burns should have guidelines on the use of gloves, plastic aprons, gowns, disposable caps, masks and eyewear. These guidelines require regular review and update. However, to date no studies have defined the most effective combination of infection control precautions for use in burn settings. It is important for staff to understand that gloves do not replace the need for hand hygiene. Evidence for the overuse or misuse of gloves has shown these practices contribute to poorer infection control practice and a risk of cross contamination [279]. A study based in 15 hospitals in the United Kingdom found that glove use was strongly associated with lower levels of hand hygiene (adjusted odds ratio, 0.65 [95% confidence interval, 0.54-0.79]; $p < .0001$) [280]. Glove usage should be integrated into local hand hygiene policies and monitored. Visual aids and reminders such as notices on the doors of patient rooms or adjacent to washing facilities can also be helpful. The WHO Glove Use Information Leaflet provides a clear and practical guide; see: www.who.int/gpsc/5may/Glove_Use_Information_Leaflet.pdf

10.2.1. *Balance of benefits and harms*

Addressing the practicalities of caring for burn patients in RLS, the Interburns® consensus group recommended that patients be managed in specific ward areas designated only for burns [281]. Basic infection control measures, the most important being hand hygiene, can be improved regardless of the level of development of the health care setting. Such measures can afford the potential huge benefit of improving hand hygiene practice and thus reducing the burden of HCAI in burn patients. The effectiveness of any intervention requires behaviors be monitored and audited to maintain patient safety and sustain improvements achieved.

10.2.2. *Values and preferences*

Health care workers' practice in regard to hand hygiene is suboptimal in most settings [262,282] and education does not always result in improved compliance [283]. Other multiple influences on behavior include resources, facilities, overcrowding and beliefs. Some professional groups are more resistant to change than others. In surveys of hand hygiene practice, nurses consistently outperform other medical staff. In the Nigerian study, the hand hygiene compliance rate was significantly higher among nurses (72.9%) compared to physicians (59.7%) ($\chi^2 = 23.8$, $p < 0.05$) [266].

Other values can affect practice; for example, health care workers are more likely to disinfect hands following contact with a patient perceived as potentially infected than with objects in the patient's environment [266,273]. Compliance with hand-washing has been found to be better in dirty high-risk situations [284].

10.2.3. *Costs*

For effective hand hygiene, simple affordable interventions are possible and highly cost effective. Five Moments for Hand Hygiene, a combination of publications that have emerged from the WHO guidelines, is a free resource including leaflets and posters, some of which have been adapted for the local

circumstances in different countries. These tools can be used for education and also to produce lost-cost visual reminders in clinical areas. See: http://www.who.int/gpsc/tools/Five_moments/en/.

Thorough hand washing with soap and water removes more than 90% of transient flora, including most contaminants. Therefore, if hands are not visibly soiled, or ABHR is not available, soap and water is acceptable. Conversely, if water or towels are in short supply, hand rub (although more costly) can be very useful.

Environmental design modifications, such as improving hand hygiene–facilities adjacent to the point of patient care, may improve compliance [285], and these can also carry cost implications.

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11. Antibiotic stewardship

Recommendation 1

Avoid the use of prophylactic systemic antibiotics for acute burns.

11.1. *Considerations in formulating Recommendation 1*

Types of antibiotic prophylaxis used in burn care include: *topical*, *general systemic*, *perioperative*, and selective decontamination by using nonabsorbable oral antibiotics administered directly by mouth or through a feeding tube. Selective decontamination is administered as either selective *digestive* decontamination (SDD) or selective *oropharyngeal* decontamination (SOD). Topical antibiotics are discussed in the wound care section.

Although sufficient evidence in the literature allows reaching a reasonable conclusion on the use of prophylactic

antibiotics in burns, most of the evidence is historical; unfortunately only one randomized controlled trial (RCT) has been published during the last 10 years, by de la Cal in 2005 [286]. On the whole, a systematic review was published in 2010 and a Cochrane systematic review in 2013.

A systematic and meta-analysis review of seventeen RCTs in burn patient populations was published in 2010 [287]. The authors included five studies in which general systemic antibiotic prophylaxis was used [286,288–291], three other studies in which perioperative systemic prophylaxis were used [288,292,293], one which used selective digestive system prophylaxis [294], and one using local antibiotic prophylaxis [295]. Using their methodology, the authors showed that systemic use of antibiotic prophylaxis given 4–14 days after admission significantly reduced mortality (risk ratio 0.54, 95% confidence interval [CI] 0.34–0.87; five trials were included). This systematic review further showed that perioperative systemic antibiotic prophylaxis reduced pulmonary complications and wound infection but did not affect mortality. It is of interest that two of the RCTs that the authors included under systemic antibiotic prophylaxis were in fact using standard antibiotic bowel preparation (Deutsch et al. [290]) and a SDD regimen (de la Cal et al. [286]). Such mis-grouping of these RCTs may have affected the findings of this systematic review. In addition, the reported trials in the review were published over a span of 40 years, during which time the practice of burn care had markedly progressed. The authors also concluded that in three of the reviewed trials the quality of the methodology (quasi-randomization) was poor [287].

More recently, a Cochrane systematic review [296] of 36 RCTs evaluating topical and systemic prophylactic antibiotics, including SDD, did not show benefits of systemic prophylactic antibiotics administered either on admission or perioperatively. It is interesting that the authors of this Cochrane systematic review examined the same papers reviewed in 2010 by Avni in a systematic and meta-analysis and reached different conclusions. Barajas-Nava et al., the authors of the Cochrane review, concluded that the available evidence is limited and in general does not demonstrate that antibiotic prophylaxis reduces the risk of burn wound infection, invasive infections, or mortality associated with infection. The authors found no evidence that general systemic antibiotic prophylaxis compared with placebo or the absence of active treatment influences any of the primary outcome variables assessed (burn wound infection, sepsis, bacteremia, urinary tract infection [UTI], or death associated with infection). The only clear benefit shown was a reduction in the incidence of pneumonia using trimethoprim-sulfamethoxazole compared with placebo; however, this result was obtained from a small trial [291] including forty participants, and with an uncertain risk of bias, as this was a pharmaceutical company–sponsored trial. The difference in the conclusions between Avni's 2010 systematic review and Barajas-Nava's 2013 Cochrane review stems from the use of different protocol designs. Avni considered mortality from any cause as the main outcome, and wound infection, bacteremia and pneumonia as a secondary outcome. Barajas-Nava, on the other hand, reported mortality due to infection of burn wounds, sepsis, or another infective complication as a primary outcome.

Mozingo et al. in 1997 showed that in major burns with a mean of 50% total body surface area (TBSA), the bacteremia rate was 12.5% (9.5% from wound cleansing and 15% from wound excision) [297]. Although it is common practice in some burn centers to administer perioperative antibiotics to cover procedures that may cause bacteremia, little evidence supports the practice [292–299]. On the other hand, prophylactic antibiotics for management of acute burns increase the risks of emergence of resistant strains of microorganisms, diarrhea, infection with *Clostridium difficile* [300], allergic reactions, and hepatic, renal or bone-marrow toxicity [301]. This practice also makes treating overt infection difficult [302].

A 2009 systematic review regarding the use of prophylactic antibiotics in children reaches a similar conclusion: available evidence does not support the use of systemic prophylactic antibiotics in the management of pediatric burns [303]. Although the review included ten articles, only four were RCTs and the others were prospective and retrospective cohort studies [304]. An RCT of 77 children with burns were randomized into either antibiotic prophylaxis (AP) or no prophylaxis (NP). Wound infection and sepsis were significantly higher in the AP group; the length of hospital stay was significantly longer in the NP group [305].

The use of SDD and SOD for critical care patients has had a recent surge of interest. De Smet et al. in a study of 5939 critical care patients showed that SDD reduced mortality by 3.5% and SOD by 2.9% [306]. A recent (2013) systematic review and meta-analysis of selective decontamination and antimicrobial resistance in critical care patients employed either digestive SDD or oropharyngeal decontamination (SOD) [307]. The authors, reviewing 47 RCTs, detected a reduction in polymyxin-resistant Gram-negative bacilli (odds ratio, OR: 0.58, 0.46–0.72) and third-generation cephalosporin-resistant Gram-negative bacilli (OR: 0.33, 0.20–0.52) in recipients of selective decontamination compared with those who received no intervention. The authors concluded that no relationship existed between the use of SDD or SOD and the development of antimicrobial resistance in ICU patients, suggesting that the perceived risk of long-term harm related to selective decontamination could not be justified by the available data.

In a more recent systematic review and a network meta-analysis published in 2014, Price et al. demonstrated a survival benefit of SDD in the general critical care patient population (OR: 0.73, CI: 0.64–0.84). The authors also showed that the effect of SOD is less certain and that both SDD and SOD were superior to chlorhexidine decontamination. They also concluded that it is possible that chlorhexidine decontamination is associated with increased mortality [308].

However, this benefit was not mirrored in the burns population. Barret et al. [294], in a RCT of 23 patients, comparing SDD (nonabsorbable antibiotics) with placebo, showed significantly more adverse events (diarrhea or gastrointestinal bleeding) in the treatment group than in the placebo group (risk ratios, RR = 3.64; 95% CI: 1.34–9.86). Although the value of SDD is emerging strongly in the critical care evidence, SDD may also have some merit in burn patients and deserves further research.

11.1.1. *Balance of benefits and harms*

Although prescribing prophylactic antibiotics for burn patients after their injuries may be perceived as beneficial, and evidence from a single RCT suggests that perioperative antibiotics can reduce their pulmonary complications [291], the risk of burn patients' developing multi-drug resistant organisms (MDROs) and consequent complications outweighs the benefits. The risk of developing MDROs may exist not only for a particular patient, but also by means of cross contamination, for other patients encountered along the care pathway.

11.1.2. *Values and preferences*

Both locally and globally, antibiotic stewardship affords the added value of preventing the development of MDROs. In settings where monitoring wound microbiology is difficult or non-existent due to a lack of microbiology laboratories, the threshold for using prophylactic antibiotics may be lowered. Prescribing prophylactic antibiotics in these circumstances may be the preferable option for burn professionals, given that sepsis is the leading cause of death in burn patients.

11.1.3. *Costs*

The cost of prescribing antibiotics in resource-limited settings (RLS) can be proportionately low compared to other costs such as salaries and consumables [309]. However, in different settings in other countries, antibiotic costs may account for up to 84% of the total drug bill [310,311] ($4.95 per patient/day), which can be a heavy burden with weak evidence of benefit. In the United States, more than 3 million kilograms of antimicrobials were used in 2009 [312]. The cost of establishing basic microbiology laboratory facilities may be balanced against the cost of lives saved. Investment in basic microbiologic diagnosis is paramount to improving standards of care.

11.1.4. *FAQs*

Q. Can prophylactic antibiotics be given immediately following the burn injury?

A. Although there is no evidence supporting this practice, in communities where streptococcal carriers/infection is widespread, simple prophylaxis may be given for 24 h only.

Recommendation 2

Develop, implement and monitor a local antibiotic stewardship program.

11.2. *Considerations in formulating Recommendation 2*

The World Economic Forum's 2013 annual report identified antimicrobial resistance as "arguably" the greatest risk to human health [313]. Implementing an antibiotic stewardship program (ASP) that includes auditing, guideline implementation, and a decision support tool improves microbial outcomes without adversely impacting patient outcomes [314]. The incidence of sepsis in burns varies between 8% and 42.5% with a mortality rate documented at between 28% and 65% [315], making it the leading cause of death in burn patients. Williams in 2009 reported that in pediatric burns 86% of death due to sepsis is caused by resistant organisms [316].

A 2013 Cochrane review showed that interventions to reduce excessive antibiotic prescribing for hospital inpatients can reduce antimicrobial resistance or hospital-acquired infections, and that interventions to increase effective prescribing can improve clinical outcomes [317]. The review also showed that restrictive methods appeared to have a greater effect than did persuasive methods, favoring the sanction of infection control specialists in prescribing certain types of antibiotics. This practice is particularly effective in emergency situations. On the other hand, persuasive intervention is more effective in the long run. One of the most effective persuasive interventions involves provider involvement in designing these interventions as well as designing the audit tools [318]. Although current evidence supporting the value of ASP is not strong, the existent data are sufficient to justify stewardship implementation, especially that of restrictive methods, a priority in all hospitals.

Antibiotic therapy should be started immediately once the diagnosis of infection and/or sepsis is made. A 6-h delay in administering antibiotics to septic patients increases mortality [319]. For greatest efficacy, when infection in a burn patient is suspected, the initial approach is to start empirical treatment and "escalate" appropriately [320]. As the chosen antibiotic must, understandably, have broad-spectrum activity, the risk of developing multi drug resistant strains always exists. In these circumstances, when empirical antibiotics are used, therapy should be re-assessed after 48–72 h [319]. Guided by antibiogram and sensitivity testing, clinicians should adapt the broad-spectrum antibiotics to the microorganisms actually causing the infection or the treatment should be stopped altogether ("*de-escalation*") [321]. The initial empirical use of broad-spectrum antibiotics, followed by de-escalation, has a direct benefit for an individual patient as well as a collective benefit of preventing the development of multi resistant strains. Individual antibiotic dosing is also essential for the effectiveness of the treatment and to avoid toxicity.

Once antibiotics are started, the interval between the doses should not exceed three times the drug's half-life. In cases of antibiotics with short half-lives, a continuous infusion should be used [322]. In the future, individual patient computed modeling that incorporates bacterial sensitivity and patient-drug pharmacokinetics will allow for individualized, accurate antibiotic dosing that can be varied according to patients' needs [323–325]. Instant knowledge of the offending organism's genomes will allow targeted therapy and the avoidance of using empirical antibiotics [326].

Antibiotics as a means to fight infection should be a part of a wider hospital strategy of infection control. Because antibiotics diffuse poorly in burn wounds, their use alone would not prevent burn wound infection and only facilitates the emergence of multi resistant bacteria [327].

11.2.1. *Balance of benefits and harms*

An ASP, if locally implemented, would have a direct patient benefit with improved patient outcomes. ASPs also offer the collective benefit of reducing the emergence of multi drug resistant microbes, an issue which presents a serious global challenge, especially given the lack of new antibiotic discovery [328]. A properly implemented ASP may prevent patient harm by minimizing the unnecessary complications of antibiotic

misuse; no evidence supports that the implementation of an ASP might cause harm.

11.2.2. *Values and preferences*

The literature shows that added value is available to burn patients by the development, implementation and monitoring of an ASP. Prescribing broad-spectrum antibiotics for burn patients can sometimes be perceived as a way to protect these vulnerable individuals from an unhygienic environment. A successful ASP combined with a robust local infection-control program should militate against this merely perceived benefit of prescribing broad-spectrum antibiotics for burn patients.

11.2.3. *Costs*

As with any other health program that requires implementation, there is an attached financial cost—mostly manpower and technical support to provide audit tools, and also infrastructure for microbiology wound surveillance. However, an ASP affords definite cost saving because of the avoidance of antibiotic misuse. This cost saving may vary from country to country depending on the relative costs of antibiotics in relation to the total cost of treating a burn patient.

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12. Nutrition

Recommendation 1

Nutritional support should be provided during the acute phase of recovery.

12.1. *Considerations in formulating Recommendation 1*

The importance of nutritional support of the burn patient has not always been recognized. Early studies of burn patients document the severe malnutrition that occurs during the recovery period. If a patient with large burns (>40% total body surface area, TBSA) was fortunate enough to avoid death by infection, he or she would almost certainly succumb to the deleterious effects of advanced malnutrition [329–331].

Glossary

Nutritional support: therapy for patients who cannot eat or drink enough calories and/or protein on their own.
Oral nutrition: provision of drinks or food that are enhanced with protein or calories; given to patients who do not consume enough protein or calories on their own, but are still able to eat and drink.
Enteral nutrition: provision of liquid food or drinks through a feeding tube, which is typically passed through the nose or mouth into the upper gastrointestinal tract, or through a surgically created tract in the abdominal wall.
Total parenteral nutrition: provision of sterile intravenous fluids containing the full spectrum of nutrition needs, including amino acids, carbohydrates, lipids, vitamins and minerals; requires central venous access.

The metabolic response to burn injury is characterized by hypermetabolism, increased protein catabolism, and weight loss. The degree of hypercatabolism is roughly proportional to the extent of injury, with significant changes in metabolism beginning when the burn size is 30% TBSA or greater, and maximizing as the burn size reaches 40% or greater [332,333].

A normal, healthy adult can survive nearly 2 months without food, dying eventually from complications related to loss of one-quarter to one-third of body protein mass. However, because of malnutrition caused by burn injury, burn patients can reach this lethal level of protein loss within just 3–4 weeks [334]. Not only does the burn's hypermetabolic response contribute directly to the risk of death, but also malnutrition weakens the immune response, further impairing the ability of burn patients to avoid or recover from infections [335]. Wound healing is also impaired with malnutrition, delaying the necessary closure of open burn wounds [336]. Skeletal muscle is depleted, leading to loss of strength and endurance, further prolonging the already lengthy rehabilitation period. Thus the overwhelming consensus opinion of experts across the globe attests to the critically important role of nutritional support in recovery from burn injury [337–340]. This is not to say that this topic would not benefit from further research [341]. Indeed, particularly relevant to the provision of burn care in resource-limited environments is the question of the cost-effectiveness of nutritional support in patients with small- to moderate-size burns. Nonetheless, the importance of nutrition assessment after injury remains unchallenged. Relevant issues that must be addressed include the magnitude of injury and any pre-existing conditions (such as protein–calorie malnutrition), which will affect the need for nutritional support.

12.1.1. *Balance of benefits and harms*

The current available evidence has established that (1) significant alterations in metabolism occur following burn injury; (2) if left untreated these changes will result in moderate to severe malnutrition; and (3) this malnutrition is a significant confounding factor making meaningful recovery

from severe burn injury less likely. The universal experience of burn health care providers for the last 4 or more decades has supported the conclusion that nutrition assessment and management are mandatory components of comprehensive burn care.

Nonetheless, aggressive nutritional support is accompanied by some degree of risk. Gastrointestinal, mechanical and metabolic problems, although rare, can all arise as a result of efforts at nutritional support. (This topic is further developed in the additional nutrition recommendations below.) If the decision is made to provide nutritional support, that action must be attended by diligence and monitoring to minimize risk to the patient.

12.1.2. *Values and preferences*

In resource-limited settings, only one or two meals may be provided by the hospital each day. The family of the injured patient is expected to provide the remaining nourishment for the day. In some ways, this may be an optimal approach to dealing with the many food preferences that exist; families are likely to provide the type of food most appealing to the patient. However, this approach permits less control by health care providers over the quantity and quality of food provided. Calories may be emphasized more than protein or micronutrients, thus leading to inadequate correction of nutrition deficiencies.

12.1.3. *Costs*

Without question, the most significant barrier to implementation of nutritional support following burns in resource-limited settings (RLS) is the lack of funding to support either dieticians or other needed resources, such as feeding tubes and enteral formulas. In the allocation of resources in restricted settings, more emphasis is likely to be placed on other personnel, such as nurses and doctors, as well as on supplies and equipment that have a more immediate role in patient care (for instance, intravenous fluids and antibiotics). Those in administrative positions must consciously allocate adequate means for providing nutritional support to those who need it.

Recommendation 2

Enteral nutritional support should be used in preference to parenteral nutritional support.

12.2. *Considerations in formulating Recommendation 2*

The only prospective comparative studies performed on burn patients date back to the 1980s, and much has changed since then, not only in terms of nutritional support but also regarding all other aspects of care. However, given the current standards of nutrition practice as well as the wealth of confirmative data from the trauma and critical care literature [342–344], the recommendation for the preferred use of enteral nutrition in burn patients can be strongly supported.

When supplemental nutrition is needed for patient care, enteral nutrition is preferred to parenteral nutrition for nearly all conditions, excepting short bowel syndrome, gastrointestinal fistulas, and bowel obstruction. This is also the accepted standard of care for patients recovering from traumatic injuries, including burns. The rationale for the benefits of enteral nutrition focus on the nourishment of gut mucosa, including intestinal epithelial cells and the intestinal immune system, which reduces bacterial translocation and enhances gut-associated immune function.

Meta-analysis of 27 prospective, controlled, randomized trials[4] concluded that parenteral nutrition is associated with a higher risk of infection compared with either enteral nutrition or with conventional oral diets using intravenous dextrose [345]. A similar review of 13 studies of critically ill patients observed that enteral nutrition as opposed to parenteral nutrition was associated with a significant reduction in infectious complications, although there was no difference in mortality rates [346]. The only comparative study of clinical outcomes in burn patients observed a higher incidence of mortality in patients fed parenterally as opposed to enterally, and concluded that this was likely due to further impairment of the immune system [347]. A prospective randomized trial of enteral and parenteral nutrition in patients with severe burns showed that enteral feeding was a more effective route to preserve gastrointestinal function and protect mucosal barrier function [348]. However, a retrospective review of a cohort of pediatric burn patients recovering from burns $\geq$30% TBSA showed no difference in catheter-related bloodstream infections or mortality between those receiving only enteral nutrition compared to those receiving a combination of parenteral and enteral support [349]. No further prospective, comparative studies have been conducted in burn patients, but the preferred use of enteral feeding has become best practice across the globe.

12.2.1. *Balance of benefits and harms*

Conventional oral feeding is ultimately preferred to either enteral feeding (such as with liquid formulas given through nasoenteric tubes) or parenteral feeding (total intravenous nutrition) because of the reduction in both cost and complications. However, many severely burned patients are unable to eat enough to satisfy the hypermetabolic response, and the reluctance to transition from conventional oral to enteral feedings may result in impairment of the immune system, delays in wound healing, prolonged rehabilitation, and possibly even death.

However, if the choice facing the clinician is between enteral and parenteral nutritional support, enteral feeding is preferable in all cases except those in which parenteral support is clearly indicated; i.e., with short bowel syndrome, gastrointestinal fistula, or bowel obstruction.

12.2.2. *Values and preferences*

In RLS, choosing between enteral and parenteral support may be irrelevant because of the limited availability of parenteral nutrition supplies. Nonetheless, in critical care units in which

[4] Conditions treated in study populations included severe short bowel syndrome, high-output gastrointestinal fistulas, severe renal tubular disease, persistent ileus or intestinal pseudo-obstruction, persistent emesis, or conditions induced by infection, inflammation, drugs, radiation or immunologic disorders.

parenteral nutrition is available, it is important to elect preferentially the option of enteral nutrition because of the potential for a reduction in complications, improved outcomes, and cost savings.

Initial attempts should be made to provide necessary protein, calorie and micronutrient support through the use of conventional oral diets. If 60% of the estimated nutrition requirements (see Recommendations 4 and 5) can be taken orally by patients with small- to moderate-size burns (40% TBSA or less), then the additional risk and expense of enteral feedings may not be worth the anticipated clinical benefits.

12.2.3. *Costs*

A clear cost benefit exists for using enteral as opposed to parenteral nutrition [350]. Indeed, if conventional oral diets are considered a form of "enteral" nutrition, then the cost of this option is drastically lower than that of the parenteral option.

Recommendation 3

Conventional oral diets or enteral feedings should be initiated as soon as possible.

12.3. *Considerations in formulating Recommendation 3*

A number of theoretical reasons justify why initiation of nutritional support within the first 24 h ("early feeding") would be beneficial. These reasons include maintenance of gut mucosal thickness and control of permeability, stimulation of gut-associated lymphatic tissue (GALT) and other immune factors such as immunoglobulin A (IgA), and reduction of bacterial translocation [351,352]. The widespread expectation has been that early enteral feeding can improve clinical outcomes, specifically by reducing post-burn hypermetabolism and ameliorating the immune response, resulting in less weight loss and few infections.

However, a Cochrane review published in 2007 [353] failed to find sufficient evidence to support or to refute the superiority of early enteral feeding compared with feedings that are initiated more than 24 h following burn injury. Three randomized controlled trials with a total of 70 burn patients were eligible for inclusion in that review [354–356] (146 other references were identified but rejected from inclusion in the review). The primary outcomes were clinical: mortality, length of hospital stay, and number of infections and other adverse events. Other secondary outcomes included weight and biochemical markers such as serum albumin, white blood cell count, and C-reactive protein. The three studies did not show any reduction in post-burn hypermetabolism, nor were differences noted in mortality rates, length of stay, infections and adverse events, and biochemical parameters. These conclusions from the Cochrane review were later substantiated in a review of clinical trials using the medical databases MEDLINE, CINHAL, and EMBASE [357].

12.3.1. *Balance of benefits and harms*

The disadvantage of early feeding is that a higher risk of complications from enteral feeding may result during the first 24–48 h after burn injury while the patient is being resuscitated from burn shock. For example, gastric ileus is not uncommon in the first day after burn injury, and could lead to a higher risk of aspiration pneumonitis if conventional oral diets or enteral feedings are resolutely provided. Similarly, patients who are incompletely resuscitated should not have direct small bowel feeding instituted because of the risk of gastrointestinal intolerance and possible intestinal necrosis. Aggressive acceleration of enteral feeding may result in increased nutrient delivery in the first 2 days after injury but has no effect on length of stay or mortality, and is associated with a higher incidence of paralytic ileus [358].

However, although there are no data to support an unwavering commitment to early enteral feeding, a limited number of clinical studies demonstrate the safety of early feeding [359–361]. Extensive clinical practice has confirmed that if pursued carefully, calorie and protein intake can begin during the initial resuscitation period. This makes particular sense if the patient's resuscitation fluids are being provided orally rather than intravenously. Early initiation of enteral feeding will also increase the likelihood of achieving nutrition goals [362].

12.3.2. *Values and preferences*

In resource-abundant settings (such as high-income countries, HIC), burn centers that have chosen to adopt early enteral feeding as mandatory in the care of patients with significant injuries (>20% TBSA) have also devoted significant resources to achieving this goal. These resources include the immediate placement of and use of radiographic guidance with nasojejunal feeding tubes shortly after admission, and the execution of protocols for advancing the rate of administration of tube feedings until a goal rate is reached. However, in the absence of convincing scientific evidence to support this approach, it is difficult to advocate creation of such policies in burn centers that are currently not utilizing early enteral feeding. Nonetheless, there are similarly no data to support the delay of nutritional support, and best practice across the globe favors the initiation of nutritional support as soon as it is practical and safe.

12.3.3. *Costs*

Indeed, as mentioned above, an enthusiastic commitment to early enteral feeding can be quite costly because of the involvement of techniques (such as interventional radiology or fiberoptic endoscopy) to ensure accurate placement of feeding tubes. Paradoxically, the initiation of early enteral feeding may be the least expensive option and the easiest to begin in RLS where resuscitation from burn shock is being provided with oral resuscitation formulas; in those settings, all that is needed for early feeding is to include light soup or broth with the oral resuscitation formula, thus introducing calories and protein at a slow, safe rate.

12.3.4. *FAQs*

Q. When is the best time to start feeding after burn injury?

A. Because there are no data clearly supporting one approach over another, the best answer is to feed as soon as the patient appears able to tolerate nutrition. If the patient is being orally resuscitated, clear broth can be given to

supplement the oral resuscitation fluid. Easily tolerated soft foods, such as clear soups or juices, and foods that are easy to chew can be started as soon as the patient is ready to eat. Because gastric ileus frequently accompanies burns for a period of 24–48 h after injury, it is unwise to force food upon a patient who is unwilling to eat. Examination of the patient for signs of peristalsis (such as bowel sounds and a soft abdomen) should help with this decision. However, the presence of a feeding tube will allow slow introduction of enteral feeding at 10–20 mL/h.

Q. What is preferable: an oral diet of regular food or enteral feedings through a tube into the gastrointestinal tract?

A. Again, without scientific supportive evidence, the best answer is based on local resources and preferences. If the patient is able to take adequate amounts of food to supply necessary protein and caloric needs, then oral diets are as effective as and certainly cheaper than commercially prepared enteral formulas. In addition, further modifying food by mashing or pureeing can help with mastication and swallowing.

Recommendation 4

For patients with burns covering more than 20% of their body surface area, a high protein diet should be used with provision of adequate calories to meet energy needs. Adults should receive 1.5–2 g of protein per kilogram body weight per day (g/kg/d), and children should receive 3 g/kg/d.

12.4. *Considerations in formulating Recommendation 4*

Increased catabolism of protein leads to losses of over one kilogram of skeletal muscle and visceral proteins a day [363]. Loss of skeletal muscle compromises diaphragmatic motion and thus respiratory function; it also contributes to debilitation and loss of strength and endurance, prolonging the rehabilitation period. Loss of visceral proteins impairs both the immune response and wound healing. Despite repletion with apparently adequate amounts of dietary protein and calories, protein catabolism exceeds anabolism and weight loss following burn injury is inevitable [364,365].

Despite inescapable weight loss following burns >20% TBSA, it is clear that high-protein diets lead to better clinical outcomes. Severely burned children who were fed 5 g/kg/d had better immune function, fewer days of bacteremia and antibiotics, and higher survival rates than similarly injured children randomized to 3.8 g/kg/d [366]. In addition, burned children treated with early burn excision and aggressive nutritional supplementation benefited from attenuation of skeletal muscle catabolism [367]. Current recommendations promote 1.5–2 g/kg/d in adults and 3 g/kg/d in children [368–374].

12.4.1. *Balance of benefits and harms*

When given in an effort to ameliorate the catabolic losses following burn injury, overzealous nutritional support can offer little additional benefit over prudent nutritional supplementation, and may be harmful. Overfeeding can result in fluid and electrolyte imbalances, hyperglycemia, and hepatic steatosis [375,376]. Indeed, early attempts to combat burn hypermetabolism with aggressive parenteral nutritional support may have contributed to patient mortality [377].

Nonetheless, supplementation with diets that emphasize adequate and appropriate amounts of protein can be delivered safely. This is particularly true if nutritional support is being provided with conventional oral diets. Overfeeding is extremely unlikely if not impossible if conventional oral diets are being used. Ensuring that the oral diet contains enough dietary protein is then the only concern. Oral diets that provide enough calories in the form of carbohydrates or fat or both, but that are lacking sufficient protein, will exacerbate the protein-calorie malnutrition that occurs frequently after burns in RLS.

12.4.2. *Values and preferences*

Dietary preferences affecting type and amount of protein intake vary widely across the world. Sources of dietary protein may be limited in some RLS because of poverty, famine or civil strife. The choices of dietary protein may also be restricted because of cultural or religious preferences, such as the avoidance of beef by Hindus, of fish by some Somali clans, and of pork by Muslims and Jews [378].

12.4.3. *Costs*

If commercially prepared enteral formulas are used for nasoenteric tube feeding, there is little concern about protein content because standard enteral formulas provide sufficient protein calories as long as the goal rate of infusion can be maintained. In fact, enteral formulas that are low in protein (such as those specific for renal failure) are usually more expensive than standard formulas.

Protein supplementation of conventional oral diets may be more expensive if the diet provided by the hospital is insufficient in protein content. In many RLS, families are expected to provide at least one meal a day to their hospitalized relatives and may need to supplement to hospital diets staple foods high in carbohydrates but low in protein, such as potato, cassava, yam or plantain [379]. In such settings, the expense of providing an acceptable source of dietary protein—further complicated by the necessity of preparing the food prior to bringing it to the hospital—may be an untenable goal for impoverished families.

Recommendation 5

Energy requirements should be estimated by formulas that use variables such as burn size and age, and weight.

12.5. *Considerations in formulating Recommendation 5*

Following burn injury >20% TBSA, expenditure of energy is determined by injury severity, level of physical activity, and frequency of infections. It has long been appreciated that large burns (>50% to 60% TBSA) more than double basal metabolic rate (BMR) if early excision of burn eschar is not performed [380,381]. Even in HIC, in burn centers using aggressive surgical approaches to early wound closure, the mean elevation of BMR is still markedly elevated to nearly 170% in patients with large burns [382].

In spite of the inevitability of weight loss after burn injury, the goal of comprehensive burn care is to minimize the amount of weight lost during recuperation. Pursuing this goal involves thorough initial and repeated assessments of nutrition status, as well as using predictions of daily caloric requirements. The initial assessment should take into account pre-existing nutrition deficiencies, such as marasmus or vitamin deficiency syndromes. Ongoing assessments should include routine (at least twice weekly) measurements of patient weight [383].

Several formulas for nutrition assessment have been derived and tested in adult and pediatric burn patients [384]. A 2009 report noted that 100% of 65 burn centers in North America use algebraic formulas to estimate caloric needs; the majority base estimates on either calories per kilogram body weight or on elevations of the basal metabolic rate (based on the Harris-Benedict equation) adjusted by injury stress factor [385]. Unfortunately, all these formulas suffer from some degree of predictive inaccuracy, most likely because of fluctuations in patient metabolism due to surgery, sepsis or inflammation [386]. Nonetheless, the use of predictive formulas has taken its place among the elements of best practice in burn centers globally.

12.5.1. *Balance of benefits and harms*

As mentioned above, predictive formulas are much more likely to overestimate than to underestimate daily caloric requirements. Thus the greatest risks stemming from rigidly adhering to estimated formulas are those of overfeeding and all its attendant complications. Conversely, the risk of using speculation based only on individual clinical assessments is that insufficient calories will be provided, resulting in exacerbation of progressive weight loss and debilitation from unchecked hypermetabolism. Yet, as is germane to this discussion, and to paraphrase Winston Churchill, predictive formulas are the worst form of nutrition assessment except all those other forms that have been tried [387].

12.5.2. *Values and preferences*

Indeed, one of the values of predictive formulas is that they can be generated by individual burn centers based on retrospective reviews of their own patient populations and experience. Using a dependent variable of weight loss, regression formulas can be constructed based on independent variables such as age, sex, body-mass index (or height and weight), and %TBSA burn area. Approximately 10 patients are needed for each independent variable included, so that a sample of 50–60 patients would be sufficient for a burn center to create its own predictive formula for minimizing weight loss.

Although some burn centers may have access to soft, flexible single lumen tubes (8–14 F), which can be used for enteral feeding, there may be limited availability of commercial enteral products. Food can be blended in a processor and administered through the feeding tube. The advantage of this approach—aside from cost-saving—is that fresh fruit and vegetables can be given, thus providing the patient with important phytonutrients. The difficulty is that sterility is difficult if not impossible to maintain, leading to the risk of gastroenteritis from pathogens administered in the blended food.

12.5.3. *Costs*

The cost of providing supplemental nutrition will vary greatly from one locale to another. Even in HIC, thoughtful consideration needs to be given to the formulas and techniques routinely used for nutritional support in burn patients because many trends currently in vogue lack scientific support. At the other end of the spectrum, in low-income countries (LIC), families of burn patients may be asked to supplement the institutional food by providing meals to their hospitalized relatives, which may further stress their already limited financial resources. Yet the argument needs to be made that appropriate nutritional support can reduce hospital length of stay and shorten healing and rehabilitation times, thus leading to quicker returns home and to work for all concerned.

12.5.4. *FAQs*

Q. Shouldn't the first step be that a nutrition assessment is completed on admission?

A. Yes, a subjective global assessment of nutrition status is part of the initial evaluation of all burn patients. It should be included as part of the complete history and physical, which seeks to determine all co-morbid factors that will come to bear on recovery from burns, such as active infections (tuberculosis, malaria, HIV).

Q. Are the stated outcomes used to determine the benefits of nutritional support appropriate; i.e., are mortality and length of stay truly attributable to nutrition, particularly in RLS?

A. Nutrition status has pronounced effects on many organ systems, but these effects may be subtle and may be difficult if not impossible to separate from the myriad perturbations effected by the burn injury. Nonetheless, it is clear what happens when nutrition status is neglected: infections flourish, catabolism proceeds unchecked, and patients will die with malnutrition.

Q. For the studies presented, is the baseline nutrition status of patients in resource-abundant settings (on whom the studies were based) comparable with the status of patients in RLS?

A. Without direct evidence, our assumption is that most patients in RLS suffer from a degree of malnutrition not seen in the patient populations studied in resource-abundant settings. The assumption must also be made that they are at higher risk of complications and death because of malnutrition.

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13. Rehabilitation: Part I—Positioning of the burn patient

Recommendation 1

Positioning of the burn patient in such positions so as to counteract contractile forces is critical in producing good functional outcomes in recovery and this positioning should be implemented along the continuum of care.

13.1. *Considerations in formulating Recommendation 1*

Further research is likely to have an important impact on our understanding of how patient positioning affects long-term functional outcomes. To date no prospective trials have determined the efficacy of burn patient positioning. Given the evidence that scars may cause contractures as healing occurs, burn rehabilitation professionals strive to position all affected areas of the total body surface area (TBSA) in the anti-contracture position associated with a specific body area. All evidential data regarding patient positioning are merely clinical observations that have been documented in the literature through the years. All current positioning regimens call for immediate intervention upon the patient's admission to the burn center. Positioning should be designed to aid in reducing edema, maintaining good joint alignment, protecting immobilized joints, promoting wound healing, and relieving pressure/prevent pressure ulcers.

The following is a guideline for positioning the burn patient from head to toe:

Head: Facial edema is acutely evident as a result of a severe burn injury involving the head of the patient. To relieve excessive edema, the patient's head may be positioned above the level of the heart. This can be accomplished by elevating the head of the patient's bed or by inclining the patient's bed as a unit at approximately 30–45°. In resource-limited settings (RLS) the position described above may be accomplished through the use of square wooden blocks (blocks measuring about 12–16 in.) that are placed on the bottom of the bed legs at the head of the bed. In the cases where the patient's hips are severely affected by the burn injury the head of the patient should be placed in the desired position by elevating the bed as a unit; this will help to avoid hip contractures that may occur if the head of the bed is elevated to 30–45°.

Neck: The neck is positioned in neutral or in a slight extension of about 15°, being careful to avoid any rotation of lateral flexion. In the case of patient intubation, care should be taken not to overextend the neck. This position can be achieved through posteriorly placing rolled towels or foam just below the neck along the scapular line. Pillows should be avoided when the neck is injured anteriorly as they may cause the neck to contract in flexion. Additionally, pillows may cause further damage to the already injured ear cartilage as a result of the patient resting his or her head on the pillow.

Shoulder/axilla: The patient's axilla should be positioned in about 90° of abduction and at 15–20° of shoulder horizontal flexion (shoulder horizontal flexion helps to alleviate tension on the brachial plexus and may prevent neuropathies caused by prolonged positioning). This position can easily be achieved through the use of pillows, foam arm troughs, bedside tables and thermoplastic arm troughs suspended from an overhead trapeze.

Elbow and forearm: Deep burn injury to the elbow may lead to the development of flexion contractures which may significantly limit functional activity. The elbow should be positioned in full extension minus a few degrees (about 5° from full extension) to avoid joint capsular tightness. The recommended position of the forearm is neutral or slight supination depending on the location and depth of the injury.

Wrist and hand: The wrist should be positioned in neutral or at a slight extension of about 10°. The hand should be positioned in 70–90° of metacarpophalangeal (MCP) joint flexion with the proximal and distal interphalangeal (IP) joints positioned in full extension. The thumb should be placed in a combination of radial and palmar abduction at the carpometacarpal (CMC) joint with slight flexion at the first MCP joint. If the severely injured hand is left unattended it will probably

develop a contracture known as a claw hand, which significantly limits the functional use of the hand.

Hip: When the injury is on the anterior surface of the body extending from the abdomen to the hip, the position of comfort is that of hip flexion. This position may lead to a contracture that limits normal spinal alignment and impairs functional ambulation when the patient is out of bed and ready to resume activities of daily living (ADLs). While the patient is supine in bed, the recommended position of the hip is full extension, 0° rotation, and at about 15–20° abduction from the midline.

Knee: Injury to the posterior knee joint may result in flexion contracture that, if persistent, may eventually lead to hip flexion and scoliosis of the spine in extreme cases. Deep injury to the anterior surface of the joint may cause injury to the patellar tendon. In order to avoid a flexion contracture and protect the joint, and until the patient is able to ambulate, the knee should be positioned in full extension minus a few degrees (about 5° from full extension), in order to avoid joint capsular tightness.

Foot and ankle: The most frequent deformity affecting the burned foot is probably equinus. This debilitating deformity may result from full thickness burn that damages the peroneal nerve causing the foot to invert and plantarflex. Early on in the recovery, the foot/ankle should be maintained in the neutral position. While the patient is supine a neutral position may be achieved through splinting or through cradling the foot/ankle with cushions and bandages. In the prone position the foot/ankle may be allowed to fall into the desired position through the use of a cut-out foam mattress at the distal leg and with the assistance of gravity forces.

13.1.1. *Balance of benefits and harms*

Despite the lack of evidence to support these positioning recommendations, we feel that clinical observations through the years have demonstrated that the positioning regimen described produces desirable outcomes in preventing contractures and deformities along the continuum of burn rehabilitation. Failure to implement a positioning protocol in the early stages of recovery may produce undesirable outcomes and may require surgical intervention to be reversed. It would be unethical at this time to conduct prospective randomized studies to determine the efficacy of patient positioning in burn rehabilitation.

13.1.2. *Values and preferences*

The described positions can be easily implemented with patients in any part of the world. In RLS, however, where obtaining thermoplastic materials (splinting materials) may be difficult, burn rehabilitation professionals can achieve the desired outcomes by constructing positioning devices with available local resources.

13.1.3. *Costs*

Modern, expensive positioning devices such as electric beds, thermoplastics, etc. may not be available in the developing countries. The positioning recommendations described above can easily be accomplished with the use of low cost materials available locally in various countries around the world.

Recommended reading

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14. Rehabilitation: Part II—Splinting of the burn patient

Recommendation 1

Use orthotic and splinting devices to achieve appropriate positioning of the body surface area when immobilization is warranted or to progressively stretch joints and maintain or promote movement.

14.1. *Considerations in formulating Recommendation 1*

To date, no prospective trials have determined the efficacy of burn-patient splinting. All evidential data regarding the efficacy of burn splinting are merely clinical observations and the opinions of experts, which have been documented in the literature through the years (see recommended reading list below).

Whereas burn rehabilitation emphasizes the importance of mobility and function, along the continuum of care a burn patient must sometimes be immobilized or will need assistance in moving his/her extremities. Anti-contracture positioning has traditionally been accomplished through the use of splinting. Orthotic and splinting devices are vital in burn rehabilitation, as they are utilized throughout the patient's recovery to obtain appropriate positioning of the body surface area when immobilization is warranted.

Currently, most burn rehabilitation specialists initiate splinting when burn injuries are deep partial or full thickness in an attempt to position the patient appropriately to aid in edema reduction and prevention of contractures. Various splint designs are utilized along the continuum of care to position joints appropriately, and maintain or promote mobility.

Orthotic and splinting devices are used to:

- *Appropriately position a body part/joint*. Deep partial or full thickness injuries are at risk of developing contractures as healing occurs if splints/orthotics are not used.

- *Support, protect and immobilize exposed tendons/joints*. Severe injuries associated with burns may include tendon/joint exposure that must be protected to prevent permanent damage and deformity.
- *Aid in edema and pain reduction*. During the inflammatory phase of recovery, edema may cause irreversible damage such as nerve compression; thus appropriate positioning through splinting may be indicated to prevent complications caused by edema.
- *Protect new grafts and flaps*. Splints may be used to protect new grafts/flaps during the postoperative immobilization period. Specialized grafting techniques may require splinting to immobilize and protect surgical sites.
- *Correct contracture/deformity*. Splints may be designed to exert certain forces on anatomic surfaces that progressively reverse/correct deformities and contractures.
- *Maintain and/or increase movement*. Static-progressive or dynamic splinting may be indicated to stabilize and/or position one or more joints, enabling other joints to: function correctly, assist weak muscles in counteracting the effects of gravity, strengthen weak muscles (by having the patients exercise against springs or rubber bands), and remodel scarring around joints or tendons.

14.2. *Splint design*

Rehabilitation specialists generally fabricate static splints throughout the wound healing period, primarily to position joints appropriately. After wounds close and the focus of rehabilitation shifts toward reversing contractures and remodeling scar tissue, use of static-progressive or dynamic splints may be indicated. Dynamic splints may be indicated to assist in moving weak or de-innervated muscles.

- Static splint: Static or passive splints should be selected when it is indicated that the affected joint or joints are to be immobilized or that movement must be restricted.
- Static-progressive splint: These splints can be adjusted incrementally to achieve a desired joint position.
- Dynamic splint: This splint achieves its effects by movement and force, and serves as a form of manipulation. A dynamic splint may make use of forces generated by the patient's own muscles or by externally imposed forces with the use of rubber bands or springs.

14.2.1. *Splint types*

Multiple kinds of splints can be selected depending on the body part with which they will be used.

- *Face*: high-temperature thermoplastic transparent face mask (full or partial), low temperature thermoplastic mask (full or partial), mouth splints (static or dynamic, horizontal, vertical or circumferential), nose splints, ear splints.
- *Neck*: anterior, posterior or lateral splint design. Watusi collar, soft neck collar (foam).
- *Axilla*: airplane splint (one-piece thermoplastic, triangular design foam wedge, three-point thermoplastic design, cast design or prefabricated commercially available design). Figure-of-eight axillary pads.
- *Elbow*: anterior or posterior (one-piece design, three-point design, cast design). Dynamic elbow flexion or extension splints. Prefabricated, commercially available designs (static-progressive or dynamic).
- *Forearm*: pronation or supination splint design.
- *Wrist*: static, static-progressive, dynamic, or cast design. Flexion, extension, deviation (ulnar, radial) splints.
- *Hand*: static, static-progressive, dynamic or cast design. Flexion or extension splints.
- *Hip*: anterior hip spica (hip extension) splint design, foam abduction wedge. A cast design may be necessary in an extreme case.
- *Knee*: anterior, posterior (one-piece design, three-point design, cast design). Static, static-progressive, or dynamic splints. Prefabricated, commercially available designs (static-progressive or dynamic).
- *Foot*: dorsiflexion, plantarflexion or neutral position (anterior or posterior design), prefabricated, commercially available design. Cast design when needed. High-temperature, custom-made ankle foot orthoses (for permanent foot neurologic problems) may be fabricated by a certified orthotist.

14.2.2. *Splinting materials*

Various materials can be used for splinting. All materials must be carefully examined and evaluated by the rehabilitation specialist prior to choosing the most appropriate material from which a specific splint is to be constructed. A wide array of low- and high-temperature thermoplastic materials can be used along the continuum of burn rehabilitation. These materials are expensive and may not be available in the resource-limited settings (RLS). Rehabilitation specialists should consider using splinting material alternatives that are available in their practice. These materials may include wood, cane, cardboard, plaster rolls, metal rods, rubber bands, foam, etc.

Splints and orthotics should:

- Not cause pain;
- Promote function;
- Be cosmetically appealing;
- Be easy to apply and remove;
- Be lightweight and low profile;
- Be constructed of appropriate materials; and
- Allow for ventilation, especially when applied over open wounds.

14.2.3. *Patient education*

Patients must be carefully educated on how, when, and for how long they need to wear their splints. Instructions must be issued on how to clean and care for the splint. All instructions must be given to patients in writing (including pictures and diagrams when appropriate) and patients should be asked to demonstrate how to apply/remove their splint. In certain cases patients may need to wear more than one splint throughout the day so the instructions issued by the rehabilitation specialist must be clearly written, and the type of splint and a timetable of splint application should be issued to the patient.

14.2.4. *Balance of benefits and harms*

Despite a lack of evidence supporting the efficacy of various burn splints, clinical observations made through the years by

experts in burn care suggest that use of burn splints and their respective guidelines (as described above) may produce desirable outcomes that (1) prevent contractures and deformities, and (2) may aid in producing functional improvement at the completion of burn rehabilitation. Failure to implement splinting protocols along the continuum of burn rehabilitation may produce undesirable outcomes in terms of mobility and function. It would be unethical to exclude splinting from burn rehabilitation protocols based on the lack of evidence to support its efficacy.

14.2.5. *Values and preferences*

The described guidelines should be taken into consideration when implementing splinting for burn survivors. In RLS it may be difficult to obtain thermoplastic materials to construct splint and orthotic devices; however, burn rehabilitation professionals can achieve the desirable rehabilitation outcomes through maximizing available resources found locally at different locations around the world.

14.2.6. *Costs*

Splinting materials are expensive and may not be available in RLS. Rehabilitation specialists can use alternative inexpensive materials such as plaster, wood, cardboard, foam, metal rods, rubber bands, etc., to design and fabricate splints. A bit of imagination and innovative thinking can serve in the design of effective yet inexpensive splints for the burn patient.

Recommended reading

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15. Pruritus management

Recommendation 1

Routine care should include assessment for intensity, duration and impact of post-burn itching (pruritus) on activities of daily living (e.g., sleep, work, school, recreation).

15.1. *Considerations in formulating Recommendation 1*

To date there is no consensus on a preferred treatment for post-burn pruritus (itch) [388] and all recommendations are based on best evidence at this time. There have been several prospective reports on the prevalence of pruritus after burn injury, demonstrating that a substantial number of patients report itch following re-epithelialization of their burn wound. Furthermore, post-burn pruritus is often a distressing sequela that affects one's recovery and quality of life [389]. These reports illustrate that post-burn pruritus is often greatest at discharge and/or following complete wound healing and then diminishes with time [388,390–398].

Despite the high prevalence of post-burn pruritus in both children and adult burn survivors, our understanding of the mechanisms of burn-related itch is limited. However, many believe that the pruritic pathway comprises both a peripheral and a central component [399] and that the mechanisms of this pathway are likely to be multifactorial in nature [400].

Clinical assessment of post-burn itching should be included in routine care. Where appropriate, the assessment should include age-appropriate instruments to help *quantify* post-burn pruritus for intensity and impact. Currently, five English-language instruments (one observational and four self-reporting instruments) have been validated and used clinically with individuals who have sustained a burn injury. The Toronto Pediatric Itch Scale is a behavioral–observational scale for use in children age 5 years and younger [401]. The Itch Man Scale (a five-point Likert scale) is useful for both verbal and pre-verbal children age 6 and older [402]. The 5-D Itch Scale is a self-reporting instrument that measures five dimensions of pruritus: degree (intensity), duration (number of hours/day), direction (whether the itch is getting better or worse), disability (impact on activities), and distribution (location on the body where the individual experiences itch). It is appropriate for use in adult patients but not as a daily measure as it reflects the 'past two weeks' [403,404] The Numerical Rating Scale (NRS) and Visual Analogue Scale (VAS) for itch are two other self-reporting instruments used to quantify post-burn itch. Both the NRS and VAS are common tools used to describe different subjective experiences, such as

itch, that exist along a continuum from 'no itch' to the 'worst itch possible' (or imaginable). The VAS or NRS for itch are often used in adolescent and adult patients. Other English-language pruritic assessment measures exist but have not been validated in the English-speaking, burn-injured population [405,406].

For non-English speaking clinicians and/or patients, assessment using descriptive terms to qualify the patient's itching is likely the best assessment strategy to use at present. Important to include with an assessment of intensity is the impact of itching on activities of daily living to include school, work, recreation, and sleep. As assessment tools are validated in other languages, adopting the use of those tools would be recommended if the psychometric analyses are within an acceptable range.

15.1.1. *Balance of benefits and harms*

Assessment of post-burn itch poses no harm. The benefits of determining intensity of post-burn pruritus far outweigh the burden of being questioned or observed regarding this common sequela. With the establishment and use of validated itch assessment tools/instruments, new management protocols can be established and tested using uniform outcome metrics. Ultimately, this will lead to improved treatment modalities.

15.1.2. *Values and preferences*

The preference for which pruritus assessment instrument to use will depend on the culture and age of the patient being assessed. There is little research concerning the cultural differences in perceptions of itch that may affect self-reported ratings. If validated assessment instruments do *not* exist for the language spoken, clinical assessment using general terms and clinician observations should be performed and documented.

15.1.3. *Costs*

The cost for reproduction of these instruments is minimal yet may still be an impediment for use in some resource-limited settings (RLS). However, if self-reporting tools are used and touched by a patient (e.g., hard copy VAS or Itch Man Scale), the instrument should be laminated such that it can be cleaned between patients and thus will not become a source of cross-contamination.

Recommendation 2

Following wound re-epithelialization, skin hydration should be promoted and dryness minimized by using skin emollients. Such treatments are recommended for use multiple times per day.

15.2. *Considerations in formulating Recommendation 2*

Some reports correlate post-injury skin/wound dryness with increased reports of itch severity/intensity [391]. This may be particularly true for wounds that require skin grafting, which typically represent deeper wounds [388].

Emollients (for example, coconut oil) and systemic antihistamines are a leading combination therapy for burn pruritus [388]. Anecdotal reports suggest the use of moisturizing agents or emollients for daily application to healed skin [407]. (For detailed definitions of emollients versus humectants and other moisturizing agents, see FAQs, Nonsurgical Management of Burn Scars, page 39). Which product to use is not well established, however many burn centers suggest using unscented or fragrance-free moisturizers and emollients [408].

Some newer publications report on other topical creams, with and without additional ingredients, which may prove useful, however further investigation is required [409,410,411].

15.2.1. *Balance of benefits and harms*

Sensitivity to any topical moisturizer may occur, thus the suggestion for use of fragrance-free products is recommended. Testing a chosen moisturizer or emollient on a small uninjured area of the body first for the development of an adverse reaction (e.g., rash, increase in itching) is also recommended.

15.2.2. *Values and preferences*

The preference for which moisturizer or emollient to use is dependent on product availability and cost.

15.2.3. *Costs*

The cost of these products will vary and should be considered when making a selection.

Recommendation 3

When available, pharmacologic treatments should be considered to minimize significant post-burn pruritus.

15.3. *Considerations in formulating Recommendation 3*

Although an optimal pharmacologic approach to management of pruritus is not supported by clinical research studies, it is supported by overwhelming expert opinion. The primary reason for this is the paucity of evidence-based studies investigating the effectiveness of different systemic and topical agents. In 2010, Goutos and colleagues performed a systematic review of therapeutic agents for treatment of burn pruritus and concluded that most studies to date did not have sufficient statistical power to allow for the recommendation of a single agent or treatment approach [407]. Nonetheless, several different pharmacologic treatment options exist, including topical medications (anesthetics), systemic oral agents, and combination therapy. Further research is likely to have an important impact on the role of pharmacologic agents in the treatment of burn-related pruritus.

15.3.1. *Topical medications*

Topical administration of medications for post-burn pruritus has included histamine receptor antagonists, antidepressants with histamine blocking properties, and creams with proteolytic enzymes, as well as the selective use of local anesthetics [412–414].

15.3.2. *Systemic medications*

Oral antihistamines are a mainstay of many treatment algorithms for burn-related pruritus [388,399].

Increasing evidence suggests that the use of systemic, centrally acting agents is beneficial in treating burn pruritus. Several investigators suggest the use of gabapentin as either monotherapy or in combination therapy with antihistamines [399,407,415–417]. Other investigators have used opioid agonists and antagonists [418].

Despite a fair amount of research to date, no clear consensus has been reached on the pharmacologic management of post-burn itch. In addition, the significance of a level or intensity of pruritus that is likely to require treatment has not been quantified nor agreed upon. Furthermore, the question remains: Is it the intensity of pruritus that dictates the need for treatment (for example, a level of 4 or greater on a 0–10 NRS for itch) or the impact of pruritus on one's activities of daily living (e.g., impact on one's ability to work or fall asleep or maintain sleep through the night)? That conclusion has yet to be determined.

15.3.3. *Balance of benefits and harms*

The decision regarding how and when to treat pruritus for any given individual must be weighed against the negative consequences (i.e., side effects) of the treatment regimen chosen. Clinicians must consider this when prescribing their use given that some of the suggested medications act via the central nervous system. The impact of the itching on one's activities of daily living and quality of life must be part of the assessment to warrant initiation of some therapies.

15.3.4. *Values and preferences*

In RLS, this decision may be based on the availability of medications, both systemic and topical. The importance of sharing outcomes in future investigations and in using standardized approaches and outcome measures (i.e., using validated itch-assessment instruments) is critical.

15.3.5. *Costs*

Given the limited data demonstrating a clear choice in burn pruritus treatment regimens, there is not a clear cost–benefit ratio in using any single pharmacologic regimen or combination therapy.

Recommendation 4

Nonpharmacologic management of pruritus is appropriate whether or not pharmacologic treatment is available. Nonpharmacologic treatments that may assist in improving comfort include skin cooling (application of cool cloths), massage (in combination with hydrating lotions), localized pressure, oatmeal preparations, and electro-physical applications such as transcutaneous electrical nerve stimulation (TENS).

15.4. *Considerations in formulating Recommendation 4*

Nonpharmacologic treatments including colloidal oatmeal, pulsed dye laser (PDL), silicone gels, scar massage, and transcutaneous electrical nerve stimulation (TENS) have all demonstrated positive clinical results for reducing post-burn itch. However, the majority of these treatments will require better clinical studies to validate their use [407,410,419–421].

15.4.1. *Balance of benefits and harms*

Depending on the nonpharmacologic treatment chosen, the benefit/harm profile will vary.

15.4.2. *Values and preferences*

The value of using nonpharmacologic therapy in the treatment of burn-related pruritus appears promising. Given the minimal cost for some of these treatments, they may be worth pursuing in many environments, including low-, middle- and high-income countries.

15.4.3. *Costs*

Given the current data demonstrating no clear choice in the use of adjunctive therapies for burn pruritus, no clear cost–benefit ratio can be cited for using any single nonpharmacologic strategy. However, several of these treatments cost little to nothing and may therefore provide greater value to the patient. This may be especially true for use of scar massage that requires the patient and/or family caregiver be taught massage therapy for healed scars and wounds. Scar massage is often combined with the application of a moisturizer/emollient, thus providing additive benefit with little cost (see: Nonsurgical Management of Burn Scars, page 39).

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16. Ethical issues

Recommendation 1

Patient autonomy must be respected, with the patient him/herself making decisions regarding treatment. If the patient is unable to speak for him/herself, then a responsible surrogate must be appointed to provide decisions regarding care. The treatment team role resides in providing the best information to the patient and/or his/her surrogate regarding the likely course of care, alternatives, and prognosis.

Glossary

Autonomy: The condition or right of an individual to administer his/her own affairs; self-determination, independence.
Informed consent: permission granted in the knowledge of the possible consequences, typically that which is given by a patient to a doctor for treatment with full knowledge of the possible risks and benefits.
Surrogate: A person appointed to act in place of another.
Physician–patient relationship: A formal or inferred relationship between a physician and a patient, which is established once the physician assumes or under takes the medical care or treatment of a patient.
Beneficence: active kindness
Nonmaleficence: the act of avoiding evildoing.

16.1. *Considerations in formulating Recommendation 1*

Respect for persons and individual autonomy are among the hallmarks of moral philosophy and the law. This principle has been codified repeatedly in biomedical ethics and case law.

The concept of informed consent for treatment was developed primarily through discussions of moral philosophy

and in the courts [422], and is fundamental to the practice of medicine. The basis of informed consent, then, is the patient's right of autonomy in choice of treatment; this is realized through the informed consent process. This right is supported by the principles of respect for persons, self-governance, liberty, and privacy [423]. All of these culminate in the notion that patients have the right to make choices for treatment that are consistent with his or her values and preferences [424].

Informed consent can be seen as authorization for medical treatment. In the case for burns, this is for treatment of the burn wound and all of its associated anatomic and physiologic changes, both local and systemic. This authorization implies autonomous decisions by the patient in regard to his or her care. This autonomy can be ceded to others, *if* made voluntarily. The process should be such that the patient's own wishes are respected, rejecting the concept that the physician should act independently in the patient's interest unless this was explicitly discussed and agreed upon or expected by both parties, and is considered for each specific treatment.

Informed consent for medical treatment has four elements: voluntary (free from coercion), decision-making capacity (legal and mental competence), disclosure (complete communication of the risks, benefits, and alternatives to treatment), and understanding of the proposed treatment and its likely implications [425]. The discussion must be made with clear explanations in a language that can be understood by the patient [426]. Common complications, regardless of severity, should be described, as should less frequent but potentially serious or irreversible risks [422,424].

Burned patients are commonly unable to provide their own informed consent because of unconsciousness or distracting effects of the injury, and thus cannot achieve capacity or understanding of the treatment and its options. In this condition, a surrogate should be found who can substitute for the patient in urgent decisions. Such a person is ideally from the patient's family or has a significant relationship to the patient [427]. Laws regarding surrogate consent and the order of persons with relationships to the patient who may act as surrogate are present in most societies. Efforts should be made to follow the established norms regarding surrogate consent in the event the patient him/herself is incapacitated.

16.1.1. *Balance of benefits and harms*

Respect for persons demands that treatment decisions for a burned patient are reached with informed consent of the patient or his/her surrogate. Benefits of the approach ensure that the patient's own values and desires with respect to their own outlook are considered.

In some emergency situations, delays that might be incurred to achieve informed consent will in fact increase the probability of harm. In these cases, emergency treatment without informed consent should be undertaken *if* reasonable persons would agree that delay to obtain formal informed consent would in fact induce harm. Otherwise, informed consent must be obtained.

16.1.2. *Values and preferences*

Many cultural differences exist in regard to the usual practice of obtaining informed consent. In some societies, the individual is expected to make his/her own decision. In others, it is expected that members of the family or other respected persons will be responsible for decisions. In general, the principle of respect for persons should be followed with the patient him/herself providing consent for treatment. If he/she chooses to cede decision-making to others, this is also an informed decision. However, this decision cannot be assumed, and all patients should be given the opportunity to determine their own care or make their decision to have others decide explicitly; it is the responsibility of the burn care provider to assure that health care decisions are made with respect to individual autonomy.

16.1.3. *Costs*

The cost of obtaining informed consent is typically not monetary, but instead involves the time and effort of the provider and the treating institution. In most societies and conditions, these costs should be considered as secondary to the rights explained above.

Recommendation 2

The best course of burn treatment based on current evidence should be made available on a timely basis, with consideration for resource availability. All treatment decisions in burn care must provide direct benefit to the patient according to his/her wishes.

16.2. *Considerations in formulating Recommendation 2*

In accordance with tradition and the established values of the physician/patient relationship, the best available treatment for the burn wound and related conditions should be recommended, and with the consent of the patient, delivered. In some situations, treatments that are commonly available in other more-resourced environments may not be feasible; even in highly resourced environments, in times of crisis such as mass casualty disasters, treatments may be limited. In these cases, the best treatment that is locally available should be delivered. This is supported by the principle of nonmaleficence [428].

Burn care is continually advancing with development of new treatments. These new treatments and the means for delivery can be scarce, however, and are therefore often associated with high costs. These costs may exceed resources in some environments in relation to other pressing interests, as resources for health care are limited to some extent even in the best circumstances. The ethical responsibility of the burn care provider, then, is to provide the highest level of care given the circumstances of his/her environment. If better treatments established in other environments are not available, it is the responsibility of the burn care system to strive to gain the resources for these treatments to deliver the best burn care possible.

The use of new treatments should be fully supported prior to implementation. Decisions regarding care should be made with the long-term interest of the patient at the forefront, and some treatments may actually indirectly increase burdens on the patient and health care system beyond that directly utilized for the treatment of interest. As

an example, use of dermal equivalents to decrease scarring may necessitate staged procedures, and thus increase the burden of care for a longer duration on the patient and health care system. Efforts, therefore, should be made to consider *all* of the costs with accommodations made prior to implementation.

Treatments with unproven benefit are sometimes considered in the treatment of burns. However, without a reasonable expectation of direct benefit to a particular patient, these should be considered research. The practice of research in humans has a long tradition of guidelines and mandates encompassed in the Helsinki Declaration and the Belmont Report [429,430]. When unproven therapies are considered, those practices codified in research ethics should be followed in order to make efforts to define potential benefit, and protect patients from undue and unforeseen risks.

16.2.1. *Balance of benefits and harms*

Considerations regarding the treatments to use in burns and their consequent resource utilization must seek a balance between benefit for the patient and the costs of treatment to the patient and to the society. The overall goal of treatment in a specific individual is explicitly to improve his/her individual outcome in accordance with the principle of beneficence [423]; this outcome should be maximized for that individual by use of the best treatments available. No patient should be forced to bear the costs of lesser burn care treatment for the benefit of another.

16.2.2. *Values and preferences*

The availability of resources to care for burned patients varies across societies, as well as according to the relative burden of the number of patients. In an environment of limitless resources, all burned patients would receive only the best possible treatments; however, resources for burn care are never limitless as we live in a world of economic realities and scarcity. The onus on the burn care provider is to provide the *best* possible treatment considering the availability of local resources for that care. Treatments that are available in resource-abundant environments may not be feasible in resource-limited settings (RLS), and in that case, the treatments should be tailored to provide the *best* care for that individual in that place at that time.

16.2.3. *Costs*

The above arguments are centered on costs and benefits, which will have many variables that themselves shift over time and according to individual patients. The maxim that must hold true in the care of burned patients is to provide the best care for him/her that can be delivered without undue costs to others.

Recommendation 3

Systems of care for the significantly burned should be devised to provide services to all those with evidence of need. Burn care services should be provided regardless of ethnicity, gender, beliefs, or socioeconomic class.

16.3. *Considerations in formulating Recommendation 3*

According to the American Medical Association Code of Medical Ethics, caregivers shall support access to medical care for all people, exemplified by this recommendation. Support should be present both in providing resources in the health care system as well as in making these resources available regardless of race, color, or creed.

Systems of health care exist in all societies, some with more resources than others. In the general delivery of health care, burns are a common injury that will be encountered. Just as some societies have more resources than others, some also have a higher preponderance of significant burns. Unfortunately, among societies a high association exists between resource limitation and the incidence of burns [431], reflecting the tragedy of poverty. Nonetheless, the ethical maxim exists that regardless of available resources, local efforts should be devised to maximize outcomes and diminish suffering in those in need according to the principle of beneficence [423]; ethically, these efforts should take place both at the individual level as well as the systems level. It is incumbent on the society to strive to increase resources to effectively treat those with burns as well as to increase direct resources toward prevention of the injury, as prevention has a higher impact than any treatment or cure. Further, these systems must incorporate availability of the same level of care for all persons in the society in accordance with the principle of justice and respect for persons [428]. The delivery of such care and its costs may be made with considerations for the personal responsibility of bearing the cost of treatment.

16.3.1. *Balance of benefits and harms*

Utilization of local resources always involves tradeoffs between many competing interests, and the same is true with health care. Decisions must be made about allocation of these resources with the intent to provide the greatest benefit to the most people. Harms should also be minimized to the greatest extent possible. For these issues related to burn care, this will involve careful efforts in the health care system at large to maximize the use of available resources, as well as efforts to gain further resources to both increase benefit and reduce harms.

In regard to allocation of burn care resources among groups in societies, it is a basic right that equivalent resources should be made available to those in need regardless of beliefs, gender, or ethnicity. This right should be upheld regardless of cost.

16.3.2. *Values and preferences*

All providers generally agree that outcomes from the delivery of health care should be maximized to the greatest extent possible, thus, the principle of providing availability of services to those in need is not really at issue. However, providers must be careful to assure that bias due to differences in background and beliefs between the provider and the patient do not interfere with treatment availability or delivery.

16.3.3. *Costs*

The above concepts are central to the concepts of biomedical ethics, and should be followed regardless of cost.

16.3.4. FAQs

Q: What constitutes 'futility' of care?

A: Futility of care can be defined as the threshold at which, with a high degree of certainty, goals of care cannot be met *at any time*, and further efforts to reach these goals are not warranted. In burns, this implies a clear definition of the goals of care (e.g., survival, level of function) and the expectation of when these goals might be met, recognizing that once an equilibrium state is reached in the course of treatment the condition generally improves with time. The resources available to deliver treatments to secure an equilibrium state (e.g., wound closure, organ support) must also be considered in the certainty decision; these resources will likely differ among potential settings such as that in high-income countries (HIC) and low- to middle-income countries (LMIC), and expectations of the available level of care and potential outcomes will differ.

Probabilities used in the determination of futility will likely change over time with technologic and organizational advances, and must be kept in mind in futility decisions. Recent examples include the development of new skin substitutes for wound closure, and the widespread use of renal replacement technologies [432], both which have improved outcomes. In accordance with the principle of respect for persons and individual autonomy, all decisions regarding futility of treatment should be made with the informed consent of the patient or his/her surrogate.

Q: What is 'palliative care' and what should it entail?

A: Once a decision for the futility of care has been reached, respect for persons and the principle of dignity of life still apply in treatment decisions. Palliative care, then, is a continuation of treatment with an emphasis on compassion, such as relief of pain and anxiety, and the emotional support of the patient and his/her significant others.

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17. Quality improvement

Recommendation 1

A burn center quality improvement program should include a regularly scheduled morbidity and mortality conference that incorporates peer review and loop closure.

17.1. *Considerations in formulating Recommendation 1*

In 1966 Donabedian attempted to summarize the available literature regarding the methodology of measuring quality in medical care. Quality, as he defined it, incorporates three components: outcomes, process and infrastructure [433]. More recently, in 1996, the United States National Academy of Sciences Institute of Medicine has defined quality of care as "the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with the current professional knowledge" (Crossing the Quality Chasm). Over the years, the terminology has evolved into a process now recognized as quality improvement (QI), which involves optimizing resources in the interest of improving medical care and patient health. The concept requires continuous monitoring of the processes involved in diagnosis and treatment, and correlation of these with actual patient outcomes. A healthy, robust QI program might include collecting prospective and retrospective data for both individual providers and for the systems in which they function. Whereas the organization is often the hospital, for a trauma or burn program, the system should include pre-hospital emergency care [434] and ideally outpatient facilities where the patients receive their follow-up care.

Although current burn-related literature does not contain publications related to QI, glimpses of burn community efforts to improve quality of care and optimal patient outcomes exist. In the early 1990s, an American Burn Association project to establish quality indicators for burn outcomes resulted in a report published in the Journal of Burn Care and Rehabilitation. This report proposed two categories of indicators: organizational (system) standards, which reflect process, and clinical outcomes, which reflect practice [435]. In 2001, a supplement to the Journal of Burn Care and Rehabilitation was dedicated to Practice Guidelines for Burn Care (http://www.ameriburn.org). Because these guidelines were never listed in PubMed, they were not widely accessible; many of

these have subsequently been revised and published in the Journal of Burn Care and Research [436–440].

The culmination of American efforts to improve outcomes for patients with burn injuries is the American Burn Association (ABA) Burn Center Verification program. The philosophy behind this quality program is outlined in ''Guidelines for Trauma Centers Caring for Burn Patients,'' Chapter 14 of the American College of Surgeons (ACS) Committee on Trauma publication *Resources for Optimal Care of the Injured Patient* (https://www.facs.org/). In spite of these programs, little exists in the medical literature to guide the development of a burn-specific QI program. A 2016 PubMed search for burn and QI yielded no publications. However, since the area of burns constitutes part of the greater field of trauma, surgery and critical care, the burn community can extrapolate some QI guidelines from the literature for those clinical areas [441–444].

In response to a perceived need for enhanced global utilization of trauma QI programs, the sixtieth World Health Assembly passed Resolution WHA 60.22 (Health care systems: emergency care). This document proposed recommendations for the development of global emergency care systems and called on the World Health Organization (WHO) to:

- determine standards, mechanisms, and techniques for inspection of facilities;
- provide support to Member States for design of QI programs and other methods needed for competent and timely provision of essential trauma and emergency care; and
- provide support to Member States, upon request, for needs assessments, facility inspection, QI programs, review of legislation, and other aspects of strengthening provision of trauma and emergency care.

The resolution led to the 2009 WHO publication of ''*Guidelines for trauma quality improvement programmes*,'' which serves as a systematic review of the indications for, benefits of and techniques for creating a trauma system QI program (WHO Guidelines for Trauma System QI). As this publication reiterates, trauma QI programs are consistently shown to improve the process of care, reduce mortality, and decrease costs. Further efforts to promote trauma QI globally are warranted. An important focus of the WHO position paper is the achievability of QI in low- and middle-income countries (LMIC). Even in the United States, burn providers lament the cost of adding quality metrics data elements to burn registries and wonder how this is feasible in LMIC, many of which do not use electronic health records. However, there is strong evidence that implementation of a structured trauma service, complete with a QI program that follows Donabedian's model of structure, process, and outcome, improves triage and patient outcomes, including mortality [441]. There are also examples of beneficial effects of robust trauma QI programs in developing countries. In a 2013 study on the impact of a trauma registry and a QI program in Pakistan, the authors reported that after implementing a formalized trauma service in 2002, patients were 4.9 times less likely to die and 2.6 times less likely to develop a complication compared with patients treated before implementation of the QI program [445]. This project illustrates the feasibility and sustainability of a QI program in resource-limited settings (RLS).

17.1.1. *Balance of benefits and harms*

A successful QI program is widely viewed to be blame free, meaning that no harm is incurred by an individual or a system. Continuous QI review and timely loop closure in a mature burn care system should lead to protocol-driven clinical care, continuous professional education programs, and if necessary, targeted interventions with noncompliant professionals. Implementation of current guidelines, pathways or protocols should include modification as new data emerge or innovations are introduced. Education programs should be broad based, integrating such inclusions as case presentations and journal clubs; priority should be given to embracing technology and including video development or web-based presentations. Targeted interventions should be uncommon but should start with individualized training or counseling, and only in rare circumstances should they result in restriction of privileges.

17.1.2. *Values and preferences*

Aside from incorporating the basic elements of a QI program, quality of care must be interpreted according to the values and preferences of the individual system. For instance, in an Australian exploration of perspectives on what constituted quality of care in rural procedural medical practices in which care was provided by generalists, it was determined that rural health professionals thought mostly about technical aspects of care but that rural patients viewed access to local care to be an important part of overall quality of care [446]. Since we know that burn [447] and trauma centers [448] tend to be regional and may involve prolonged patient transport times, consideration should be given to ensuring that patients' perspectives are addressed as a part of quality of care. Furthermore, the above-mentioned observations underscore the point that patients' perspectives toward quality burn-center care highlight the need to develop technologies that provide support services in local communities.

Although Donabedian is best known for defining quality based on assessment of outcomes, process and infrastructure, he also proposed framing health care quality by means of seven additional attributes [449]:

(1) Efficacy: the ability of the care to improve patient health;
(2) Effectiveness: the degree to which attainable health improvements are realized;
(3) Efficiency: the ability to achieve optimal health improvement at the lowest cost;
(4) Optimality: the most advantageous cost–benefit ratio;
(5) Acceptability: conformity to patient preferences regarding access, patient-provider relations, amenities, outcomes, and cost;
(6) Legitimacy: conformity to social preferences concerning all of the above; and
(7) Equity: fairness in the distribution of care and its effects on health.

These individualized elements of assessing quality of health care underscore the need for incorporating regional values and preferences into burn and trauma center quality programs.

17.1.3. Costs

In a 2012 survey of trauma centers in high-income countries (HIC) regarding attitudes toward trauma QI programs, the investigators reported that one of the primary opportunities to improve trauma QI was to ensure the provision of adequate resources [450]. Dedicated human resources, the purchase and maintenance of registry software, and establishment of loop closure mechanisms as outlined above require time and money. However, studies in the European Union have demonstrated that implementation of internal QI strategies positively affect hospital outputs, including patient-centeredness [451] and lower rates of adjusted hospital-associated complications [452], which ultimately decrease overall costs of care [453]. A report of the relative costs of a QI program determined that even though the structure and infrastructure, and outcome measurements, generate costs associated with monitoring and feedback, reducing complications results in reductions in costly hospitalizations or procedures [454]; furthermore, the economic value of a QI program needs to take into consideration patient preferences [455], functional status, and quality of life.

Recommendation 2

A quality improvement burn program should include a registry that employs quality metrics which are benchmarked against burn-specific clinical norms.

17.2. Considerations in formulating Recommendation 2

The US National Quality Forum (NQF, http://www.qualityforum.org) identifies three main benefits to measuring outcomes:

- Measures drive improvement. Health care providers who review performance measures can adjust care, share successes, and probe for causes;
- Measures inform consumers. Consumers can consult national resources such as HospitalCompare.hhs.gov to assess quality of care, make choices, ask questions, and advocate for good health care;
- Measures influence payment. Payers use measures as preconditions for payment and targets for bonuses, whether it is paying providers for performance or instituting nonpayment for complications arising from NQF-designated Serious Reportable Events.

Starting in the 1970s, Dr. Irving Feller established the National Burn Information Exchange, a database developed with the lofty goal of improving burn care quality improvement, regional health care planning, resource allocation, and research and prevention efforts. This system required participating burn centers to submit data on treatment methods and outcomes via punch cards, which were used to establish baseline standards for the burned patient's care and survival. Eventually this effort evolved into the American Burn Association National Burn Repository (ABA NBR), which reports on incidence, etiology and acute outcomes. The 2015 NBR Summary Report (2015 NBR Annual Report) represented a combined data set of acute burn admissions from between 2005 and 2014, and included 203,422 records from 99 burn centers in the US, Canada, and Sweden.

A 1992 publication on trauma system guidelines advocated that successful trauma QI depends on the development of a computerized trauma registry [456]. As with burn data repositories, initial trauma registries focused primarily on mortality and hospital length of stay as outcomes of interest. With the development of the ACS National Surgery Quality Improvement Program and the Trauma Quality Improvement Program (TQIP), recognition of the need for more granular outcomes data is increasing. Unfortunately, as evidenced in the US Center for Disease Control and Prevention's National Health System Network's health care-associated infection (HAI) data (CDC NHSN) and in the University Health system Consortium Database [457], burn outcomes and general surgery or trauma outcomes do not correlate. Therefore, the burn community must develop a means to track outcomes that can be used to benchmark burn-specific results. Analysis of 4 years of data in the Burns Registry of Australia and New Zealand (BRANZ) indicates that a burn QI database is feasible; but initial data indicate that burn center profiles vary considerably suggesting a need to understand how variations in practice affect patient outcomes [458]. Just as the US trauma community has created the Trauma Quality Improvement Program (TQIP), the international burn community could develop a BQIP program that could include hospital-acquired conditions, long-term outcomes as well as the traditional patient and injury data elements. Stratified reporting could allow for burn centers to benchmark against similar sites—either by burn center size, country income status, or geographic location.

17.2.1. Balance of benefits and harms

With the continually increasing US focus on tracking physician outcomes and the US government's introduction of a Merit-Based Incentive Payment System that requires physician participation in a Physician Quality Reporting System, such a BQIP program could be essential for burn center financial survival. As QI programs expand globally, ministries of health will likely use such data to determine funding levels for burn and trauma programs. One important consideration in registry development is data veracity and completeness of the record [455]; whereas inaccurate data will compromise a QI program [455], built in validation procedures and continuous monitoring can ensure data reliability.

17.2.2. Values and preferences

Comparing outcomes between sites in HIC and LIC will not add value to burn center QI programs because of variances in burn etiology, treatment options, resources, outcomes, capabilities of tailoring burn registries to the local burn center, and benchmarking outcomes data against comparable sites. One potential benefit of an international BQIP database that includes sites from both HIC and LIC as well as from rural and urban burn centers would be the opportunity to identify whether the quality of burn care services is equitably distributed across groups defined by age, race, sex, and income [459]. This would create research and advocacy opportunities that could enable health policy debates about distribution of the quality of burn care.

17.2.3. Costs

Registry development and maintenance require resources [450]. The burn community will need to find solutions to subsidize the cost of software for burn centers with limited resources. However, most studies indicate that the costs of tracking clinical outcomes data are outweighed by the beneficial effects on hospital outputs and lower complication rates [452].

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